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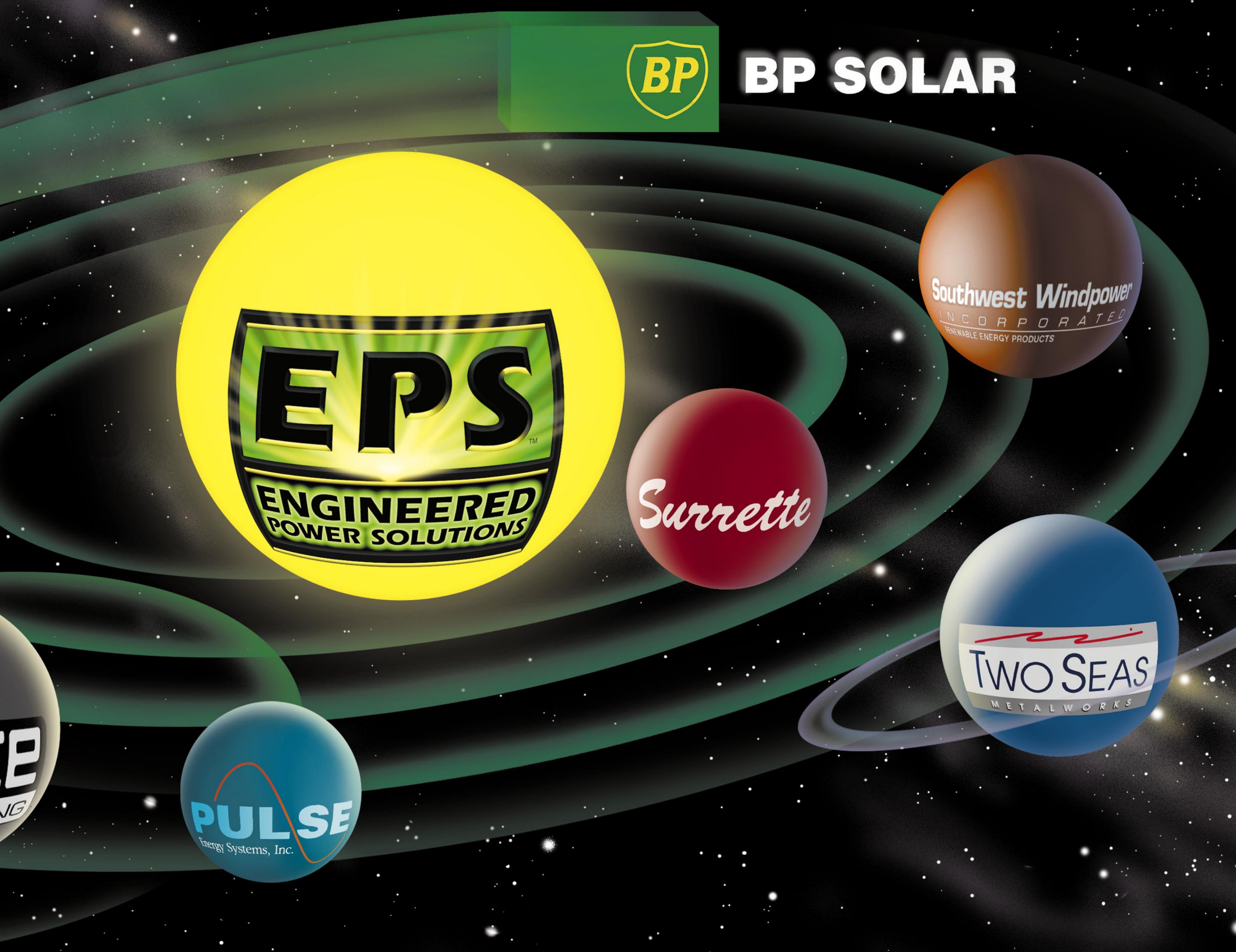
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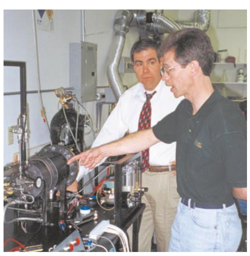
THE HANDS-ON JOURNAL OF HOME-MADE POWER

Issue #72 August / September 1999

Features



More Features

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Cover: Solar Guerrillas climb the 80 foot wind tower at the Midwest Renewable Energy Fair to fly their colors.

Things that Work!

Guerrilla Solar

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At 3 PM on 17 June 1999, Bill Haveland was killed in a motor vehicle accident in Neilsville, Wisconsin. He was on his way to the Midwest Renewable Energy Fair to demonstrate a wind machine he had recently designed before installing it at his new home in Cook County, Minnesota.

Bill had an incredibly adventurous life. He was born in St. Paul, Minnesota, July 19, 1950. After high school graduation, he worked and roamed all over the world. He lived and worked in Prudhoe Bay, Alaska, and cycled through Nepal, New Zealand, and many places in between. He lived for quite a few years in Costa Rica, working with renewable energy development, design, and installation. Bill recently moved to Cook County to start a new life close to his family. He recently published an article in Home Power, entitled Induction Motors for Small-Scale Hydro.

Bill had a passion for the environment. In his travels he saw how people have damaged the Earth. His simple life, financial support, hands-on involvement in organizations like Greenpeace, gentle diet, and intimate knowledge of the ways of walking through jungles and forests touched all who knew him. We will miss his energetic approach to life.

We particularly respect Bill's persistence in making things technically correct. That's not easy in a new field where images and wishful thinking often dominate decision making, and where Murphy's Law sometimes dominates Ohm's Law.

Bill's activism included working for the past six months to gain support from Minnesota state agencies to revisit outdated net metering and interconnection rules in order to help the smallest of renewable developers connect their systems economically and sensibly to the grid. It was an unfinished challenge, among many.

We've lost one of the "renewable energy brethren" who also worked for environmental and social justice in Central America. Living to make the world better can mean sacrifice, however, and we know that during his years in Costa Rica he was frustrated by the difficulty of making a living. This struggle is shared by many working in renewable energy and in the developing world. Bill carried the burdens of both.

And we're newly aware of the need to express our appreciation and love for all those dedicated, unique characters in our field and the contributions they make. We wonder just what Bill and St. Peter said to each other at those pearly gates…

It is sad that Bill often felt that the world didn't appreciate his efforts and now he is suddenly gone. Or is he? Let us remember him with the phrase Central Americans use to honor their dead and hold them present in their hearts: "Bill Haveland, presente."

People

Joy Anderson
Russ Barlow
Mike Brown
Sam Coleman
Windy Dankoff
Scott Ely
Skip Goebel
Anita Jarmann
Kathleen Jarschke-Schultze
Stan Krute
Don Kulha
Al Latham
Don Loweburg
Burke O'Neal
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John Wiles
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"Think about it…"

"We Gotta TAKE the Power Back"

—Zack de la Rocha
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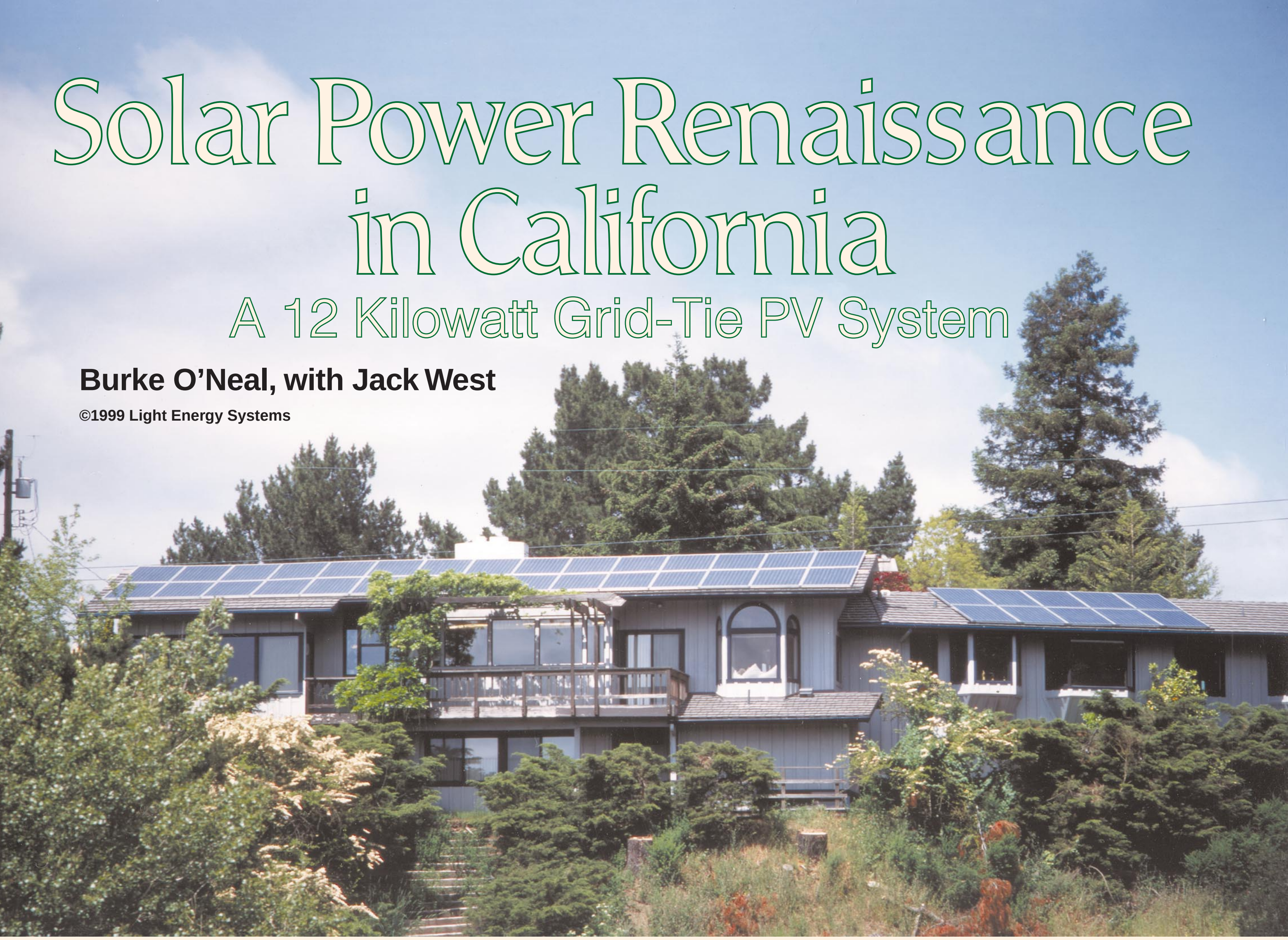


Norman and Janet Pease's 12,000 watt grid-intertied PV system powers home and car.

My best friend and I designed our first solar electric system six years ago while we were both in college at the University of Wisconsin, Madison. It was a modest 275 watt stand-alone photovoltaic (PV) system, with a bicycle-powered backup generator (see *PV in the City, HP37).* PV was practically unknown in utility-serviced cities. At that time, a utility representative told a local newspaper that PV systems were too costly and inconvenient to ever catch on for utility-connected homes.

A year ago, I moved to California and took a job with Light Energy Systems (LES). This solar contractor has over 19 years of experience in the San Francisco Bay Area and has installed hundreds of systems totalling more than 120 kilowatts. That utility representative was wrong! Utility-tied customers *are* buying PV systems.

PV Comes to the City

PV energy systems have come a long way since my college days. The "backwoods" testing grounds have proven them to be extremely reliable. Technological advances and increased demand have lowered the cost of PV panels and the supporting electronic equipment. Inverters operate seamlessly with the utility grid, with no inconvenience.

The interest level in solar energy is the highest it has been since the solar tax breaks in the late 1970s and early '80s. Net metering laws and government incentives such as the buydown program in California may signal the renaissance of residential solar power. This article will walk you through the entire grid-tie process—initial site visit to final commissioning—on a 12 KW residential PV system in Orinda, California.

Legislative Support

California Senate Bill 656, known as the Net Metering

Janet "fills" the Honda EV Plus. Daily driving consumes about 450 KWH of solar energy each month—less than one quarter of the PV's summertime output.

Law, allows California residents to sell electricity back to the grid from residential PV systems, wind systems, solar thermal-electric systems, and fuel cells. All the publicly owned transmission utilities—Pacific Gas and Electric, San Diego Gas and Electric, and Southern California Edison—are required to pay full retail price for this home-generated power up to the net zero meter reading on a yearly basis. Some other transmission utilities are participating as well, so it's worth contacting your local utility if you are interested in net metering. If home-generated power exceeds what the residents use in their house in a year, it is donated to the utility. The requirement for a utility to accept home-generated electricity ends when generating capacity equals 0.1 percent of a utility's peak electricity demand. In the case of Pacific Gas and Electric (PG&E), this is 17 megawatts, or approximately 5,000 residential-sized systems.

The California buydownprogram, Senate Bill 90, outlines distribution of the US$540 million Renewable Resource Fund. Funded by the electric utility ratepayers in California, this program is designed to support existing, new, and emerging renewable electricity generation technologies. US$32.4 million of this money has been set aside to provide rebates for residential and small commercial renewable energy systems (10 KW or less; PV, wind, and fuel cell). The rebates are structured into five buydown blocks, starting at $3 per watt of installed PV and scaling down to $1 per watt as the money is distributed.

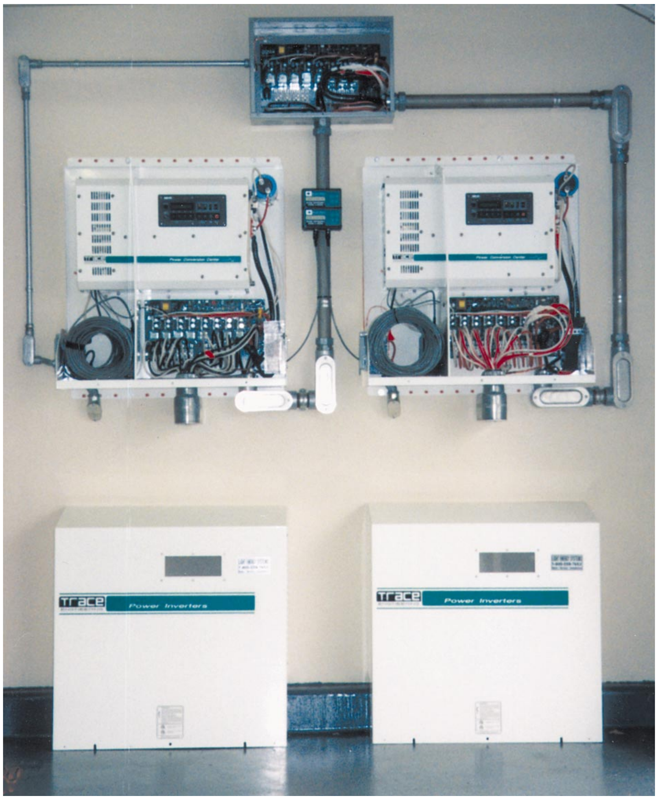
After the rebate is reserved, the contractor or homeowner has nine months to install the system. As of May 15, 1999, 285 rebate reservations have been made for residential PV systems. These constitute about 25 percent of the US$3 per watt rebates. About 80 systems have actually been built (18 of which were completed by LES). To be eligible for the rebate, PV systems must be installed by a licensed solar or electrical contractor, a licensed engineering firm, or by the homeowner. PV systems must carry a five year warranty on all the parts and labor if not installed by the homeowner.

The Pease Residential PV System

Norman and Janet Pease's PV system was designed by Jack West, a senior PV systems engineer at Light Energy Systems. It includes an impressive 12 KW array in a straight grid-connected arrangement with no battery backup. Their system uses a single meter (nothing special here—just a standard analog watt-hour meter like most homes have) to measure the difference between the electricity supplied by the utility and the electricity generated by their PV system. Imagine the gratification of seeing the utility meter spin backwards on a sunny day!

Norman and Janet have been interested in renewable energy and electric cars since the energy crisis of the 1970s. They lived on a ranch in the early '70s, about six miles (9.7 km) from the utility grid. PG&E would have charged them about US$80,000 to run a line to the ranch house. Instead, they spent a fraction of that money on a wind turbine, battery storage, and a gasoline generator for backup. They didn't purchase an electric car then because Norman didn't think the technology provided enough reliability or range. When he saw the Honda EV Plus with its 80 mile (129 km) range, he found an electric vehicle that he could feel good about. He uses it every day and it has proven to be very reliable.

Their new 3,500 square foot (325 m^2) house in the Bay Area sports a Sun Frost refrigerator, extensive compact fluorescent lighting, and even an 18 watt solar fountain. Environmental concerns motivated Norman and Janet to invest in a PV system. Norman says, "We were talking with our neighbor about our electric car when he said to us, 'Even without gas, you are still burning coal



Two Trace 5548 sine wave inverters push energy back at PG&E. Enclosure covers sit on the floor.

to charge that car.' That inspired me to look into a more environmentally sound way to produce that electricity."

Initial Site Visit

We began our site visit by giving Norman a quick overview of the different types of PV equipment and configurations available. Then we discussed their loads and the capabilities of residential-sized PV systems. As might be expected for a large suburban home in the Bay area, the average load was in excess of 100 KWH per day. Next, we looked over the site for possible PV locations. After seeing his glorious, unshaded, southwest-facing 65 by 12.5 foot (20 x 3.8 m) roof with an adjoining 30 by 12.5 foot (9 x 3.8 m) roof, PV module location was obvious.

With the PV array location decided, we took all the necessary measurements (roof type, rafter spacing, sheathing material, etc.) to design a PV system that would supply as much of the electrical load as possible. We ran a complete shading analysis using a Solar Pathfinder. And we also took a close look at the service entrance to determine if there was space for a backfed breaker or if we would have to do a line-side connection (as permitted in *NEC* section 690-64).

With all of Norman's questions answered and all the information we needed, we went back to the shop to draw up some different design options and pricing.

Reserving the California Rebate

Once we arrived at an agreement with Norman on the exact design and price of the system, we put together a contract and got to work immediately on reserving the free money! As with most of these systems, the Peases' rebate of US$3 per watt was easily reserved. We sent the California Energy Commission (CEC) a completed, one page Reservation Request Form with a signed purchase order, along with a copy of Janet and Norman's monthly utility statement.

In an effort to prevent public misconception about PV capability, the CEC decided to base the rebate on the AC rating of the system. This is calculated by multiplying the module's PTC (PVUSA Test Conditions) rating by the PVUSA approved peak efficiency of the inverter. PVUSA (Photovoltaic Utility Systems Applications) is an independent PV testing, development and educational organization funded primarily by electric utilities. The PTC rating is based on more realistic field conditions than the STC (Standard Test Conditions) rating that manufacturers typically use for their PV modules.

For the Pease residence, the 269 watt PTC rating of the modules times the 96 percent inverter efficiency gives a 10.3 KW AC rating. When multiplied by the US$3 per watt rebate amount, this yields a hefty US$31,000 rebate on their system. The total system cost, including components, tax, permits, design, and installation, was US$71,543 after the rebate.

City and Utility Permits

Before construction of Norman and Janet's PV system could begin, we had to get the required permits from the City of Orinda. In this case, they only required an electrical permit. Since PV panels add very little weight to the roof, many building departments waive the structural permit. For this system, the electrical permit fee was US$84.38. We sent the building department several electrical schematics and a schematic showing our mounting strategy.

In order to get approval from PG&E to begin the project, the owners had to sign a Net Energy Metering and Energy Purchase Agreement (NEMA). This included a requirement for adequate insurance coverage "as specified in chapter 18 of the NEMA." As in most cases, the Peases' existing homeowner's insurance was adequate.

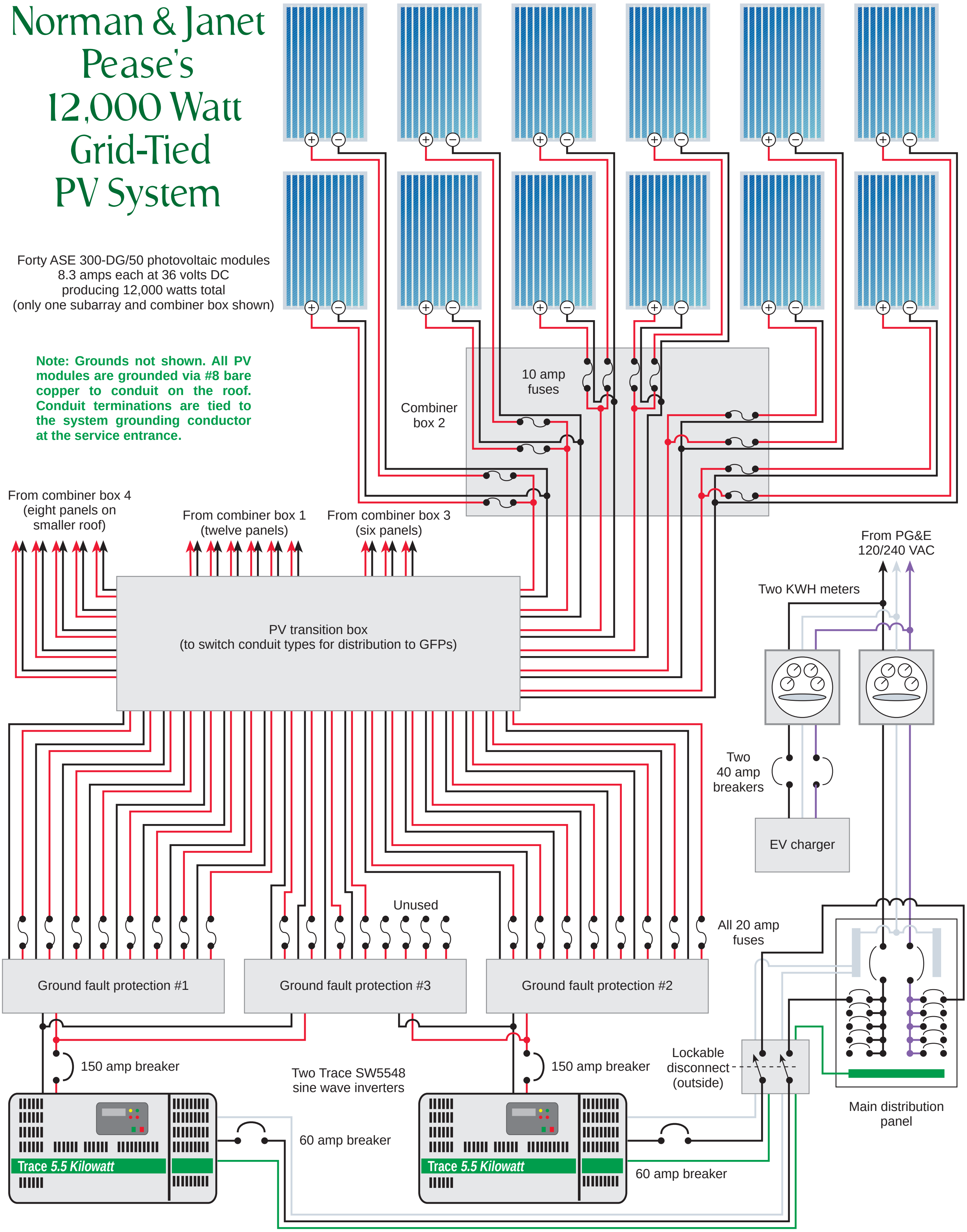
PV Panels

After we looked at how several different PV modules laid out on the roof, the ASE 300-DG/50 modules were clearly the best choice. The price was competitive, the large module area significantly reduced installation costs, and two rows of modules fit perfectly on the roof

Norman & Janet Pease's 12,000 Watt Grid-Tied PV System

Forty ASE 300-DG/50 photovoltaic modules
8.3 amps each at 36 volts DC
producing 12,000 watts total
(only one subarray and combiner box shown)

Note: Grounds not shown. All PV modules are grounded via #8 bare copper to conduit on the roof. Conduit terminations are tied to the system grounding conductor at the service entrance.



(2 ASE modules are 12 foot, 5 inches (3.78 m), and the roof was 12 foot, 6 inches (3.81 m), ridge to gutter). In the final design, we laid out thirty modules on the main roof and ten more on the adjoining roof.

We always pay very close attention to aesthetic issues. We placed the modules as close together as possible to minimize the “gapped” look. In order to minimize visual impact, we placed the roof-mounted combiner boxes and conduit runs carefully. Though we could have fit more modules on the adjoining roof, we decided to stop at 12 KW for several reasons. There were no reasonably priced low input voltage inverters available in the 12 to 15 KW range. The easternmost section of the roof had a little shading. And the California Net Metering Law only applies to systems of less than 10 KW AC (which is the final PTC AC rating of this system).

Mounting Hardware

Though the roof on this residence is made with unusual aluminum shakes, our standard LES Z-bracket mounting hardware worked fine. The LES Z-bracket is a mounting system that we designed several years ago. It consists of Z-shaped aluminum pieces that span the rafters and allow the modules to be easily clipped into place. These mounts insure that the modules line up and all penetrations are into the rafters. Mounting into the less stable sheathing can cause leaks.

The mounts also allow us to set a 1/4 inch (6 mm) thermal expansion space between the modules and a 2 inch (51 mm) air space under the modules for adequate cooling. The forty modules are mounted with four rows of LES Z-brackets running across the roof. The mounting hardware is almost completely hidden by the modules when viewed from the ground.

Inverters

We used two Trace UT-SW5548PV inverters because they can handle the 36 VDC nominal output of the modules. Norman also liked the idea of having the parallel connections at the inverter. With this wiring arrangement, he could use a clamp-on ammeter to measure the output from individual module pairs without having to get up on the roof. We mounted the inverters in the garage near the service entrance. They are configured to produce standard 3-wire, 120/240 VAC power.

Wiring

Since the modules are 36 volts DC nominal and the inverter operates at this voltage, we didn’t need to make any series connections. The integral tray cable (type TC) output from each module on the lower row was fused (with a 10 A fuse) and then wired in parallel with the module above it. This wiring was done in one of the four roof-mounted combiner boxes which feed into a transition box (for changing conduit) and then down to the ground fault protection (GFP) units.

Since the Trace GFPs included in these inverters were not large enough to handle 6 KW of PV input, we added a third GFP to handle eight of the modules. All the wiring between the combiner boxes and the GFPs is 90° C (194° F) THHN enclosed in 2 inch (51 mm) EMT. DC output from each GFP was paralleled and routed to a 150 A breaker (which had to be retrofitted in place of Trace’s standard 110 A breaker). From there, DC output continues to the DC input on the inverter. All wiring was designed to meet or exceed NEC standards and all DC runs were sized for a maximum one percent voltage drop.

Lockable Disconnect and Metering

Even though it is redundant and not required by the *NEC,* PG&E required a lockable disconnect. The inverter AC outputs were routed through the lockable disconnect before terminating at a double pole 50 A breaker in the main distribution panel.

Unlike most grid-tied PV systems, the metering was a bit tricky at the Pease residence. They had a “time of use” (TOU) meter which they were required to install when they bought their Honda EV Plus. The utility uses this meter to encourage EV users to charge at off-peak times. The utility bills up to 30 cents per KWH during the day, and 5 cents per KWH between 12 midnight and 7 AM.

Under normal circumstances, PG&E would just come out and replace the TOU meter with a standard analog meter. But since Norman had an electric vehicle, it caused great confusion at the PG&E office. He was required by law to have TOU metering for the EV, but he was not allowed to have a TOU meter with his PV system.

After many discussions with PG&E and the building department, we finally agreed to install a dual meter adapter. This device, manufactured by Marwell Co., put the house and PV system on one standard analog meter and isolated the EV on its own TOU meter.

Final Inspections and Commissioning

Once the installation was complete, we contacted the building department for the final inspection. Luckily, the inspector on this job had attended a PV workshop that Jack West taught with Bill Brooks from PVUSA! Unlike many inspectors, he had a reasonably good understanding of PV systems. He quickly ascertained that the system was installed properly and signed off the permit.

With the city's approval, we prepared for the last hurdle—PG&E approval. Our luck held out and we were sent a knowledgeable PG&E engineer whom we had seen on two previous PV jobs. He verified that the inverters were what we had specified, checked for a lockable disconnect, and then passed us with flying colors. With all the inspections out of the way, we cranked up the system and verified that all of the equipment was operating properly.

While Norman and Janet were enjoying their solar electricity, we got to work on claiming the rebate award that we had reserved. It was as easy as sending the CEC a one page Reservation Claim Form, a copy of the signed-off building permit, and a copy of the final purchase invoice. The CEC cut the rebate check within thirty days of this submittal.

Spinning Backwards

Though we aced the PG&E inspection test, we did end up having a minor problem several months after the installation. Norman received an amusing letter in January from PG&E's Revenue Protection Supervisor. It warned that "a recent inspection revealed some irregularities with the electric meter which is causing the meter to rotate backwards." We all had a good laugh.

System Performance

After eight months of monitoring the system, Norman has found that their inverters typically crank out between 33 and 37 amps (at 120 VAC) on sunny days. With the exception of an inverter capacitor that burnt out (it was covered under Trace's warranty), the system has been operating flawlessly now for over eight months.

The system should give them many years of trouble-free renewable energy. The panels are warrantied for twenty years and should last thirty years or more. The system is backed by Light Energy System's full five year parts and labor warranty.

Future Addition

Norman and Janet live in a very suburban area in Orinda, California, with houses scattered along the road winding up a hill. Because they are at the end of a utility line, they experience outages about once a month. Though they had originally decided against batteries, they are now reconsidering the battery backup option.

Above: The Honda EV Plus charging station.

Left: KWH meters for house and car, and the lockable system disconnect.

As Norman put it, "We have all of this incredible equipment on our roof—why should we be at the mercy of our utility?"

An Environmental Investment

Norman and Janet spent a lot of money on a PV system, but definitely got more than their money's worth. Norman's EV is now completely pollution-free. And they now have the satisfaction of knowing that most of the electricity for their home is being generated (or accounted for) by clean PV power. The EV uses about 450 KWH per month, which would be almost half

the PV system's output in the winter or less than a quarter in the summer. Norman puts about 60 miles (97 km) on his EV every day.

According to typical Bay area power mix averages, Norman and Janet's PV system will, over its life, prevent more than 960,000 pounds (435,456 kg) of CO_2 pollution, 7,900 pounds (3,583 kg) of SO_2 pollution, and 3,600 pounds (1633 kg) of NO_x pollution. And this doesn't even include the radioactive waste and destructive river damming that they are preventing.

Norman and Janet also got a lot of money back from the state. About 30 percent of the total system cost was paid for by the buydown program, which is funded by the utility ratepayers of California.

A year ago, Norman and Janet were spending over US$300 per month on electricity. After installing the solar electric system, replacing a 1960s frost-free refrigerator with a Sun Frost, and installing compact fluorescent lighting, Norman says, "My utility bills are not much more than the $5 service charge!"

Access

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this is page 17

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Residential Fuel Cells: Hope or Hype?

Russ Barlow

A Plug Power LLC technician evaluates a prototype for the Plug Power 7000 residential fuel cell system. The system will provide an output of 7 KW, enough to power an average-sized home.

Imagine a furnace that not only heats your home, but also quietly produces economical and eco-friendly electrical power. Even better, what if this device could use a number of portable fuels, including propane? This may sound like home power nirvana, but if this technology lives up to its developers' promises, it may herald a new era in residential electrical power.

Almost Heaven, Pennsylvania

I became interested in fuel cells after I purchased a piece of rural property in the Laurel Highlands about 50 miles (80 km) east of Pittsburgh, Pennsylvania. Planning to build has forced me to consider the need for electrical power. When the local utility engineer gave me the bottom line for the 3,500 foot (1.07 km) line extension, I got sticker shock.

The utility wanted over US$15,000, and that didn't include the cost of the right of ways. Not only was it expensive, but they wanted me to pay them to cut down my beautiful trees in order to install ugly power poles. I thought that maybe underground lines might be the solution. "No problem," the utility engineer said, "just double the price."

I was beginning to think that my great deal on this property might not have been so great after all. There had to be a solution. I needed practical answers that would allow me to be my own power company. My search led me to *Home Power* magazine. I purchased the outstanding *Solar3* CD-ROM and scoured its archives for ideas. I soon had some answers.

Which Do You Want First?

Bad news: the winter daily average of just over two hours of full sun here ruled out cost-effective PV power. Good news: my building site, located high on an exposed open hill, was a good candidate for wind power. My mate seemed a little amused by my scheme. With a wife's keen insight, she asked only two things: "What do we do when the wind stops blowing?" and

"We will have air conditioning—right?" More bad news: I realized that some form of backup power would be needed. And unfortunately, I knew what that meant—a big, expensive, noisy, polluting generator. So much for my rural serenity! There had to be a better way.

As my search continued, I learned of a little-known technology that several cutting edge companies are hurriedly preparing to bring to market. The reward for the winners of this race will likely be huge. These devices have been widely used by NASA in the manned space program over the last three decades to provide reliable electrical power. Even though Sir William Grove first discovered the principles of this technology in 1839, technological advances have only recently made fuel cells affordable.

Hoping that this technology was the answer to my problem, I set out to learn as much as I could about it. While there are a number of companies developing these systems, my schedule allowed time to visit only three. I set out to visit the companies that seemed closest to actually delivering a commercial product. Only two of these were willing to indulge me in a visit.

A Fuel What?
Fuel cells combine hydrogen and oxygen without combustion to produce electricity. Water and heat are the only byproducts of this reaction. The process combines oxygen from the air and hydrogen extracted from any one of a number of suitable hydrogen-containing fuels. The result is DC electrical power produced with far greater efficiency than most of the other non-renewable generation methods, such as internal combustion engine generators. The efficiency of fuel cell systems is approximately 30 to 40 percent.

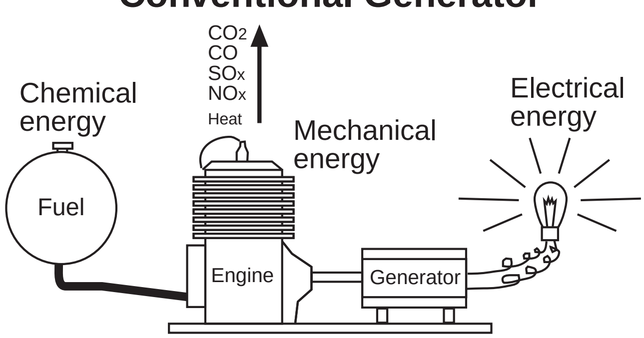
The promise of fuel cells for the on-site production of electricity is great. Many say fuel cells may do for the power industry what desktop computers have done for the computer business. Just as cellular phones and

Dr. David Edlund (right), founder of Northwest Power Systems, explains the features of their very compact and efficient fuel processing unit to the author.

satellite TV have "unwired" their respective industries, fuel cells may herald a new age in electrical power distribution.

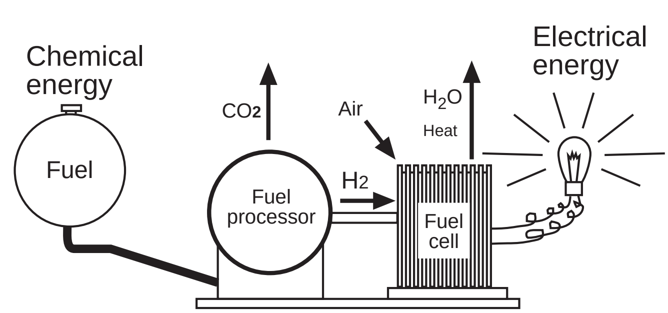
As most readers of *Home Power* have long known, there are many advantages of onsite electrical production. For developing countries, which have not

Conventional Generator



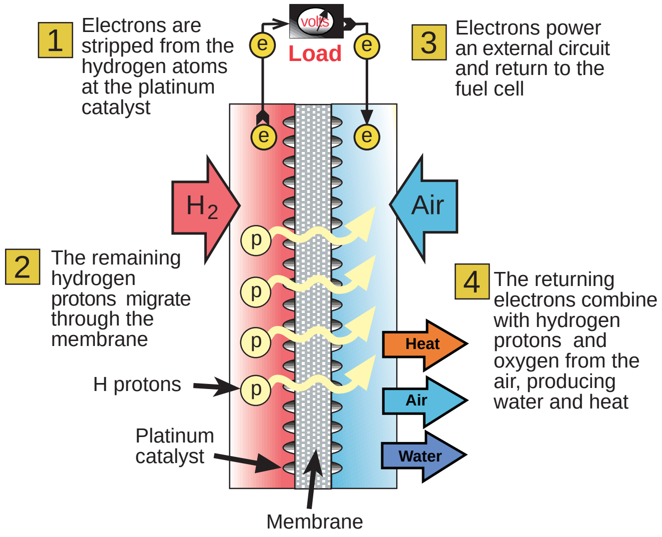
Efficiency = 15–20%
noisy, dirty

Fuel Cell Generator



Efficiency = 30–40%
quiet, clean

How a Fuel Cell Works



already made massive investments in electrical utility infrastructure, the rewards are even greater. The residential fuel cell may well be the vehicle by which the masses learn to think "outside the box" when it comes to their electrical power.

Fuel cell systems have a purpose similar to the conventional generator that many already use for primary or standby power production. Chemical energy from fuel is converted to electrical power.

In the case of a generator, fuel is converted to mechanical energy by an internal combustion engine. This mechanical energy in turn drives an electrical generator or alternator to produce electrical power. The primary byproducts are heat, CO_2 (carbon dioxide), and water. With most fuels, there are also some nasty emissions including CO (carbon monoxide) and various oxides of nitrogen and sulphur. Typically, the energy efficiency of these internal combustion generators is approximately 10 to 20 percent. That means that about 80 to 90 percent of the potential energy in the fuel is not converted to electricity.

The fuel cell power system likewise converts chemical energy to electrical power, but with a considerably simpler and more efficient path. First the fuel is converted to hydrogen by a series of chemical reactions in a processor. The resulting hydrogen is then combined with oxygen from the air in the fuel cell to produce electrical power in a single step.

Regardless of the fuel used, the chemical byproducts of the complete process are almost entirely CO_2, water, and nitrogen. Considerable low-grade heat suitable for home heating also results.

Heat

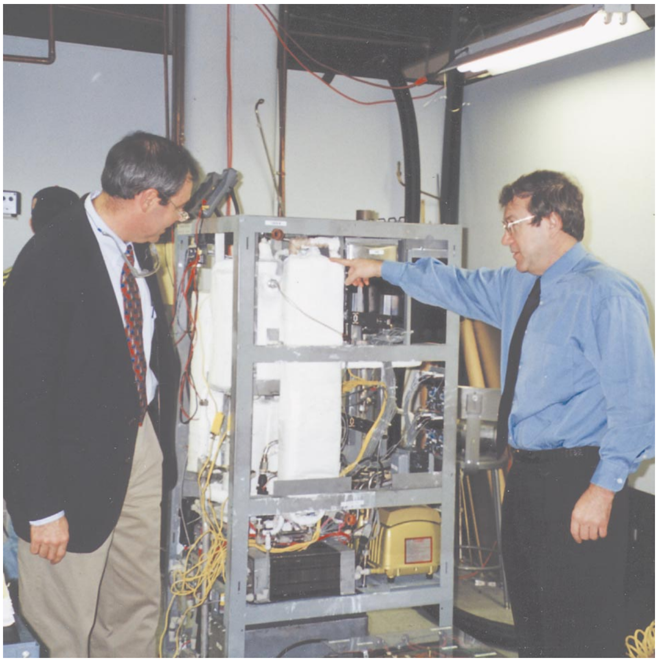
The fuel cell system produces waste heat that is easily used for home space and water heating. A simple heat exchanger is all that is needed to make the transfer of fuel cell heat to the home. In fact, most fuel cells use air or water cooling to regulate temperature for better efficiency. The plumbing for heat exchanging is already there and requires little additional cost.

One prototype system uses a single machine as both a furnace and a fuel cell generator. When home heating requirements exceed the waste heat produced by the fuel cell system, additional natural gas is added to the burner to make up any deficit.

Waste heat from engine generators is seldom used due to the carbon monoxide threat and the inconsistent availability of the heat. Fuel cells, in contrast, pose no such hazard and continuously produce some level of usable heat.

In a typical American home, the energy consumed for electrical power (except heating) and the energy consumed for domestic hot water heating are about equal. The heat byproducts from a fuel cell system just about perfectly meet the water heating needs for the average home. One manufacturer's system produces about 1.3 KW of recoverable heat energy for every 1 KW of electrical energy generated.

An American Fuel Cell employee points out the insulated reformer on their RPG-3K fuel cell system. The system can deliver heating in addition to electrical power of 3 KW continuous and 10 KW peak.



Benefits Of Residential Fuel Cells

What are the benefits of fuel cells in producing electrical power? More specifically, what advantages might they provide to the residential home power user?

1. Conversion Efficiency

Fuel cells offer an efficient way to convert chemical energy directly into electrical energy. As any mechanic knows, the fewer moving parts, the better. The fuel cell stack itself is the picture of simplicity, quietly producing electrical power without a single moving part.

2. Grid Independence

I don't need to preach to regular readers of this magazine about the benefits of onsite power production. In addition to the well known benefits, fuel cells offer several other advantages. First, locating power generation at the point of consumption allows the recovery of any heat generated. This heat can be used to further increase overall system efficiency. This co-generation should eventually allow fuel cells to produce electricity at costs below current grid rates.

Second, the typical 7 to 8 percent losses in power line transmissions are eliminated, and so are the large power line capital costs. Finally, fuel cells offer freedom from concerns about grid reliability and weather related interruptions. Third world countries, with no existing electrical distribution infrastructure, have shown a special interest in residential fuel cell systems. In many of these countries, utility grid transmission and distribution losses approach 50 percent, largely due to theft.

3. Grid Connection

Strangely enough, fuel cells also offer many advantages when connected to the grid. So many advantages, in fact, that utility companies are major investors in several of the fuel cell development startups. Connecting fuel cells to the grid allows utility companies to incrementally increase capacity without the capital outlays required in building new power plants. Unlike PV or wind power, residential fuel cells are available to supplement grid power on demand, regardless of weather, day or night.

4. Environmental Advantages

Residential fuel cell systems offer numerous ecological advantages compared to current utility power production. The operation of the fuel cell itself combines hydrogen and air, with water as the only byproduct. Fuel processing units, also called reformers, are able to convert various fuels into useful hydrogen. Ideally, CO_2 is the only byproduct of this reforming process.

The almost doubled electrical efficiency of the fuel cell means that it produces only about half the greenhouse gases of other non-renewable forms of electrical

The Northwest Power Systems 5 KW mobile demonstration fuel cell system. Note the fuel cell located on the right side of the unit.

generation. Utilization of waste heat for water or space heating even further reduces the relative amount of CO_2 emissions. Traditional internal and external combustion engines also make emissions that create smog and acid rain.

Low noise profile is another environmental advantage. A fuel cell system is typically less than one fourth as loud as a comparably sized gas or diesel generator, so it has a minimal impact on the quiet of a rural setting.

5. Renewable Compatibility

As reliable distributed power production becomes available, it will be much easier for users to create hybrid systems utilizing PV, wind, and microhydro. Fuel cells produce direct current, just as these renewable sources do. Batteries and an inverter are part of both types of systems. Whether renewable systems are added to an existing fuel cell system, or a fuel cell generator is added to an existing renewable system, the combination is a natural and easy one.

6. Fuel Flexibility

Power systems based on fuel cells offer great flexibility for the homeowner. Multiple portable fuels can be used, including propane, natural gas, methanol, ethanol, diesel, and gasoline. Just about any liquid or gas hydrocarbon fuel can be used as a source for hydrogen atoms in the cell.

This innovative fuel processor by Northwest Power Systems can convert a number of fuels into high purity hydrogen to power a fuel cell stack.

Other interesting renewable fuels that can be used with a residential fuel cell system include natural gas made from biomass and home distilled ethanol. Solar-produced hydrogen could also power a fuel cell unit without the need for complex fuel processing, and it would be totally emission-free.

7. Ease of Use and Maintenance
Fuel cell systems run continuously. Compared to a generator set, they operate at low temperatures and have very few moving parts. These systems should require only periodic maintenance and replacement similar to your home furnace.

Fuel Cell Drawbacks
Despite all of their advantages, there are still a few issues that may cloud the short term outlook for fuel cell use in residential applications. What obstacles stand in the path of this new source for renewable energy systems?

Northwest Power System's palladium alloy filter produces extremely pure hydrogen gas, and is good for at least six months service before replacement.

1. Cost
Although pricing for fuel cells continues to drop at a rapid pace, there is still a ways to go before it will be widely affordable. As with any new technology, those who jump in first will no doubt pay a premium price for a less capable product than those who wait. I think anyone who has bought a computer in the last five years can appreciate this phenomenon. The value of fuel cell systems can be fairly appraised only by comparing costs and benefits to competing technologies.

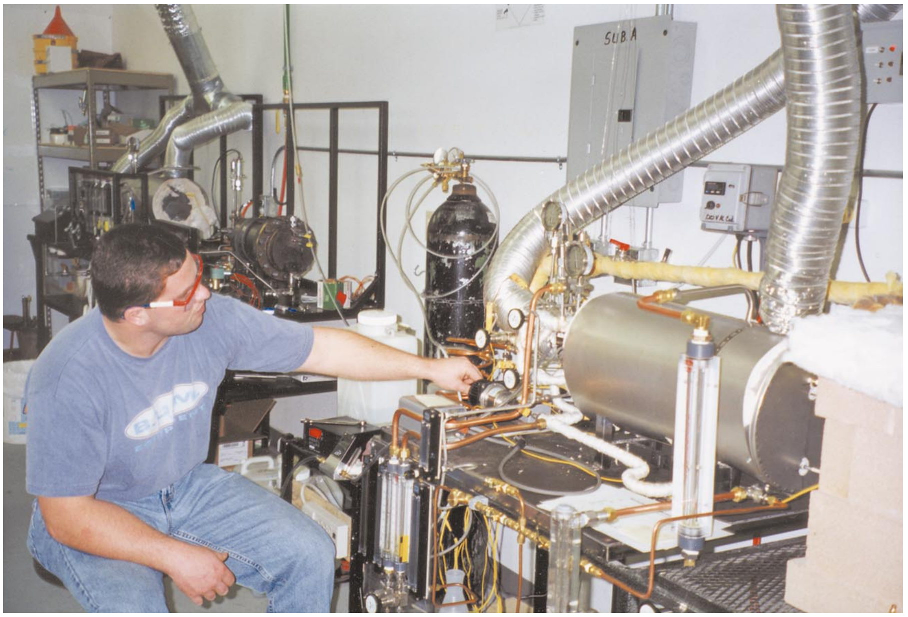
Current initial estimated cost for a turnkey 5 KW fuel cell system is about US$6,000 to $8,000. From this total, about 40 percent of the cost is associated with the fuel processor. The next largest expense is the fuel cell stack, accounting for 27 percent of the total. Power conditioning (18 percent) and controls (15 percent) are the remaining costs for a complete system.

2. Unproven Technology
Although considerable testing goes into any new product, we all know that only after large-scale deployment do many of the bugs show up. There will be risks for those who embrace this technology in its infancy, just as there were with early wind and PV systems.

3. Continuous Parasitic Loads
Unlike an engine-driven generator, which can start and produce power almost immediately, fuel cells work best when operated continuously. This means that the internal loads associated with their operation are present even when no power is produced. Usually about 10 percent of the generator's maximum output, this parasitic load is essentially a fixed cost for having power readily available.

Fuel Cell Basics
A fuel cell is an electrochemical device that silently produces direct current electrical power without combustion. Some people have likened a fuel cell to a battery in which the stored power is never depleted, but is constantly being replenished. Although the electrical response of a fuel cell to loads is similar to that of a battery, the electrochemical process is considerably different.

Just like a battery, the core of the fuel cell consists of two electrode plates—the anode and the cathode. In the fuel cell, however, these bipolar plates are separated by a polymer membrane electrolyte. This membrane is coated on both sides with a thin layer of platinum catalyst. At the anode side of the membrane, hydrogen fuel catalytically dissociates into free protons (positive hydrogen ions) and electrons.



A technician tests a fuel processor that runs on kerosene and produces up to 50 liters per minute of hydrogen containing about 2 ppm of CO.

In a sort of reverse electrolysis, the free electrons are conducted in the form of usable electric current through the external circuit. The protons migrate through the membrane electrolyte to the cathode side. There they combine with oxygen from the air and electrons from the external circuit to form pure water and heat. This proton migration through the membrane gives this type of fuel cell its name: the proton exchange membrane (PEM) fuel cell.

Although there are other kinds of fuel cells, PEM fuel cells show the most promise for residential applications and are the type used in all systems currently under development. This is largely due to their relatively low operating temperatures (under 100° C; 212° F) and favorable costs.

Recent gains in technology have reduced the amount of costly platinum catalyst required by a factor of almost 100. New, cheaper, and more effective membrane materials have continued to lower costs. Until now, fuel cells were all hand built. But mass production soon promises to bring costs to consumer levels. Just as cheaper silicon chips enabled the home computer revolution in the late 1960s, inexpensive fuel cells are poised to dramatically change the home power industry.

The electrical potential, or voltage, produced by each individual cell is limited by the reactants supplied to the cell. The theoretical maximum for a hydrogen and oxygen cell is 1.23 V, but typical values in current cells are about 0.7 V. To produce higher voltages, individual cells are stacked one against another, wired in series.

Current produced by the cell is directly proportional to the cross-sectional area of the cell where the reaction takes place. Thus, by varying the size and number of layers in the fuel cell "stack," it is possible to custom build a unit in order to meet a wide range of DC electrical requirements.

A Typical Residential Fuel Cell System

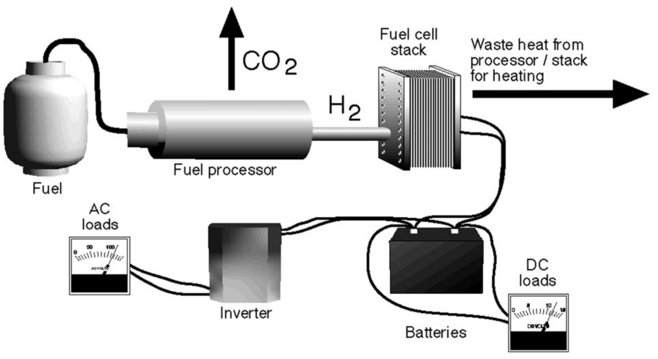
Although the fuel cell is the heart of the device, there are other important components that make up a residential fuel cell system. First, the fuel processor must convert usable fuel into pure hydrogen for use by the fuel cell stack. Next, the fuel cell stack converts this hydrogen into direct current electrical power. Finally, as in most renewable energy systems, power must be stored and conditioned for consumption, using batteries and an inverter.

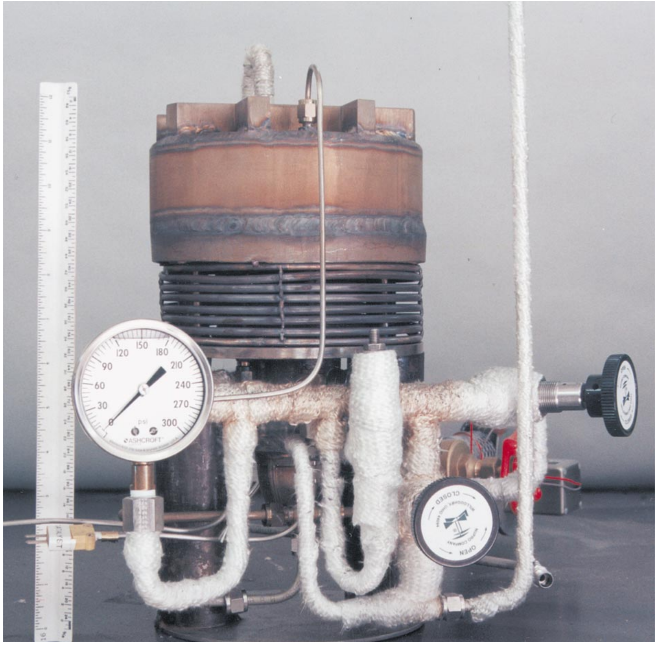
Fuel Processor

The fuel processor is what really makes residential fuel cell systems practical. In order to operate, fuel cells require extremely pure hydrogen. Typically this must contain CO concentrations of no greater than 50 parts per million (ppm) with less than 10 ppm desirable. The job of the fuel processor is to take an available fuel and convert it in sufficient purity and quantity to run the cell. At the same time, it should eliminate the undesirable emission byproducts of the conversion.

The majority of fuel processors currently under development for residential fuel cell systems utilize the following process. First, the fuel processor removes

Simplified Residential Fuel Cell System





This remarkably compact fuel processor by Northwest Power Systems can deliver enough high purity hydrogen to power a 1 KW fuel cell.

sulfur from incoming fuel by utilizing a bed of zinc oxide. The fuel, steam, and air react at about 1,500° F (816° C) in a process called steam reforming. The result is hydrogen gas that contains excessive amounts of carbon monoxide.

Carbon monoxide is reduced by a water shift conversion reaction, during which large amounts of the carbon monoxide react with steam to produce CO_2 and additional hydrogen. Finally, the remaining carbon monoxide is almost eliminated through a selective oxidation reaction that creates CO_2. The resulting hydrogen gas is then of sufficient purity for use by the fuel cell stack.

An Innovative Exception

An exception to this fuel processor model was the unit I saw during my visit to Northwest Power Systems in Bend, Oregon. Their rather simple fuel processor utilizes steam reforming like the other processors, but removes the additional carbon monoxide in a unique way. Their process is borrowed from an approach long used by the hydrogen gas industry. The carbon monoxide-contaminated hydrogen gas is filtered through a membrane that allows only the hydrogen to pass through.

The filter is made up of about 20 membrane layers of palladium alloy foil, each only one thousand of an inch (0.025 mm) thick. It produces hydrogen with carbon monoxide levels of about 2 ppm. This purity is almost twice as good as any other reforming method. Gases that do not pass through the membrane are looped back and burned to heat the steam reformer. “This method of hydrogen purification was our starting point, and we built our fuel processor backward from there,” explained Dr. David Edlund, founder and president of Northwest Power Systems.

The result is a fuel processor which is far less complex, is much smaller, and costs less. While I was at their lab, I observed these units producing large quantities of very pure hydrogen while using methanol and kerosene as fuels. Dr. Edlund showed me a small processor, about nine inches in diameter and only six inches high (23 x 15 cm), that could produce sufficient hydrogen to support a one kilowatt fuel cell.

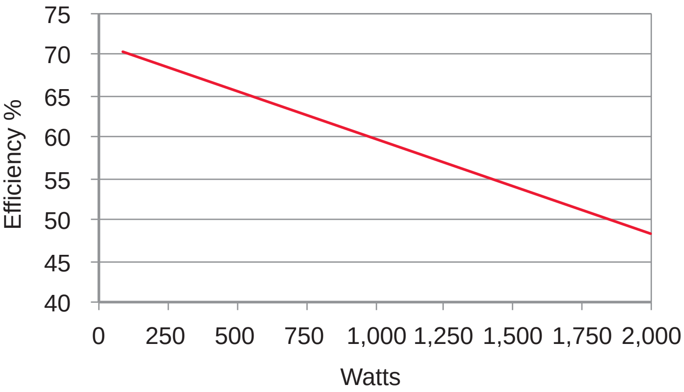
Edlund originally conceived of the concept for use on sailboats. Noisy generators are a great distraction to the purity of sailing, and he saw the quiet, small fuel cell generator as an answer to this problem. The real beauty of fuel cells for small systems is that the electrical efficiency of the fuel cell stack is actually higher at lower loads. Unlike an internal combustion power generator, whose fuel consumption remains high even at low loads, the fuel cell seems ideally suited for all phases of an efficient battery charging profile.

Fuel Cell Stack

The fuel cell stack converts hydrogen and oxygen into electrical power and heat energy. The typical PEM fuel cell operates at approximately 150° F (66° C). Hydrogen from the fuel processor and oxygen from the ambient air are combined to produce power. During my visit to American Fuel Cell Corporation in Boston, I got a close look at several fuel stack assemblies and their individual components.

The company’s founder, David Bloomfield, explained to me that it’s a long way from theory to a viable fuel cell. The hydrogen and oxygen must be delivered in a continuous and uniform way to the membrane. A second problem is maintaining the delicate humidity

Fuel Cell Stack Efficiency



balance in the cell. Much like a human lung, the moisture level has to be just right. Too much humidity can clog the membrane, inhibiting proton movement. Conversely, if the membrane dries out, breaches can develop, rendering the cell inoperable. The final hurdle to overcome, according to Bloomfield, was developing a mechanism to maintain the uniform cell stack temperature, allowing maximum electrical performance.

Each individual cell is made up of two flow field plates with a series of channels routed into the surface. The channels are designed to evenly distribute hydrogen and air to both sides of the proton membrane assembly that separates them. The membrane assembly consists of two porous carbon or graphite electrodes (cathode and anode) each with a thin layer of platinum catalyst. These are bonded to either side of the proton exchange membrane. Individual cells are assembled together to create the fuel cell stack.

Fuel cells react to loads much as batteries do. As the load is increased, the voltage drops to a point where there is no useable power. This is shown in a polarization curve that plots cell potential (volts) versus cell current density (amps/cell area).

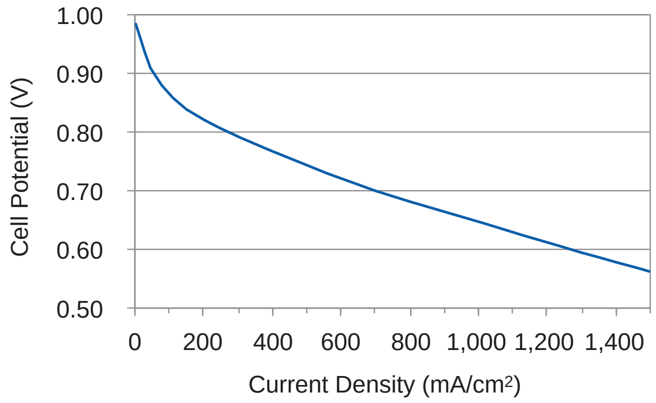
Typical fuel cell stacks convert hydrogen to electricity with an efficiency of approximately 55 to 60 percent. Other components within the residential fuel cell system further reduce overall efficiency to about 30 to 40 percent.

Thermal and Water Management System
This system maintains the fuel stack and fuel processor in thermal and mass equilibrium. It uses pumps, fans, heat exchangers, and controls, which create a constant power requirement on the fuel cell generator whenever it is running. The total parasitic load for existing residential fuel cell systems is about 250 watts. During my visit to American Fuel Cell, Bloomfield said that reducing this load by half is one of his highest priorities.

Cold startup of most fuel cell systems is a somewhat lengthy process. Up to twenty minutes is required to produce the steam needed and to bring the system into equilibrium. Because of this, fuel cell systems are designed to run on a continuous basis. For a typical system, this “phantom load” would consume about an additional half gallon (1.9 l) of propane daily, regardless of power requirements.

Power Conditioning System
Power conditioning in fuel cell systems is very similar to that of PV and wind systems that have been detailed in *Home Power* for years. DC power produced by the fuel cell stack is used for battery charging and for providing AC power through an inverter. A battery bank or some other storage mechanism is necessary because the fuel

Fuel Cell Polarization Curve



This polarization curve shows the relationship between voltage and current for an individual cell in a typical fuel cell stack.

processor cannot respond to instantaneous requirements placed on the fuel cell.

The fuel cell can respond very quickly to load demands, if provided with ample hydrogen and oxygen. But there is no way for the fuel processor to anticipate an upcoming need and produce and distribute hydrogen quickly enough. Although hydrogen could be produced in advance and stored in anticipation of a need, none of the systems I saw used this approach. Batteries also allow for load leveling so that peak loads can temporarily exceed the continuous maximum output available from the stack.

No Buyer’s Guide Yet
When I set out to explore what was on the horizon with regard to residential fuel cell systems, I hoped to be able to present a nuts and bolts comparison of soon to be released products. I envisioned a chart that one could use in selecting a system for home use. Unfortunately, my research has revealed that most systems are still in the prototype stage.

While a number of companies have proven fuel cell designs, not many have developed viable fuel processing units. Even fewer have actually made prototype turnkey systems designed for residential use.

The Major Players
American Fuel Cell Corporation has probably done the most complete work toward development of a viable residential fuel cell system. During my visit there, I saw their prototype, the Residential Power Generator (RPG-3K). It was neatly packaged into a single case, able to process natural gas, and produced up to 10 KW. These folks have really done their homework and have an early lead on many fronts. They have designed and built their own fuel cell stacks and fuel processors. The unit I saw was being readied for shipment to a German natural gas utility for testing.

Fuel Cell System Components

Component	*Efficiency*	*Cost*
Fuel processor	79%	40%
Fuel cell stack	57%	27%
Power conditioning	95%	18%
Control	90%	15%
Overall	39%	100%

The company's projections show that new homes with natural gas available could easily use an RPG-3K in place of a furnace and have electricity and heating at less than current rates. Retrofits of existing homes were also competitive with grid-connected prices.

American Fuel Cell's president expressed an interest in developing even smaller units to work with PV and wind power systems. "The environmentally friendly nature of our fuel cells just seems to make sense as a way to augment renewable systems," he explained. "Fuel cells are plainly the cleanest way to produce electrical power from non-renewable fuel sources."

Northwest Power Systems has an innovative and apparently successful approach to the difficult problem of fuel processing. In October of 1998, they demonstrated their methanol-powered fuel cell system on a 2,250 square foot (209 m^2) residence that they disconnected from the grid. The additional heat co-generated during the test was utilized in heating a 460 square foot (43 m^2) attached garage.

Their demonstration unit is three feet wide by three feet deep and three and a half feet tall (0.9 x 0.9 x 1.07 m). It was taken on a road trip throughout the northwestern U.S. to conduct similar residential demonstrations. When I observed the unit operating in their lab, it was remarkably quiet, producing only a subdued hiss. They also showed me a similar processor in their lab, running on kerosene and producing similarly pure hydrogen.

Northwest Power System's David Edlund sees the small size of the company as an advantage during this period of residential fuel cell evolution. "If we come up with a better idea or a new way of doing something, we have a meeting in the morning, and by afternoon we're already moving in that new direction," he explained. It was obvious here, as at American Fuel Cell Corp., that people are excited about fuel cells.

Plug Power, near Albany, New York, has also operated a demonstration unit powering a home. They were joined in their development and marketing efforts by a major partner, General Electric. Plug Power claimed that the proprietary nature of their research would not permit them to allow me on their premises. Repeated attempts for an invitation to visit or a phone interview were declined. I could take a hint, and gave up.

Their press package was lacking any real technical details. Further investigation revealed that their much-publicized fuel cell demonstration home had been powered by hydrogen from a large truck parked nearby. Plug Power seems to be focusing its marketing efforts towards grid-connected customers. They promise to deliver residential electrical power at rates below those offered by the current utility companies.

Other Players

Government research grants have placed much of the focus in the fuel cell industry on automobile applications. Ironically, the technical problems of automotive fuel cells are great compared to those of stationary, residential applications. Only recently, as technological advances have lowered the price of fuel cells, has private investment shifted the focus towards the residential market.

There are a number of companies that I did not visit that are currently developing residential fuel cell systems. Avista Labs in Spokane, Washington has developed a unique approach to fuel cell design. Unlike traditional stacked-plate architecture, which requires the entire unit to be disassembled for repair, they have devised a modular design which allows "hot swapping" of individual modules while the unit remains online. These units use no expensive graphite plates in their manufacturing process which leads to lower costs.

Energy Partners, in West Palm Beach, Florida, has long been a leader in PEM fuel cell development. They have provided high-performance fuel cell stacks for research in the automobile industry. Recently, they began to produce composite graphite bipolar plates. Suited for mass production, this technology will reduce Energy Partners' cost for this major component from US$100 to less than US$2 apiece. Energy Partners is in the testing stage for their NuPower line of residential fuel cell power systems.

Ballard Systems, of Burnaby, British Columbia, Canada, is another company involved in development and testing. A large, well-capitalized company, Ballard has produced many fuel cell innovations for the automotive industry. They have also delivered large commercial fuel cell power systems for use by commercial utilities. According to their press package, their 250 KW PEM fuel cell remains the most powerful in the world.

Ballard has focused mainly on the automobile industry and large commercial applications. They have announced their efforts to develop residential power systems based on fuel cells but have not yet detailed any products. Their strong technological experience will guarantee them a position in the market if they pursue it.

H-Power, located in Belleville, New Jersey, was a pioneer in the commercialization of fuel cells. They presently have a manufacturing facility producing fuel cells for commercial sale. They have sold a number of hydrogen-powered fuel cell systems to the New Jersey Department of Transportation for use on portable highway warning signs. Though they have made public their intention to enter the residential fuel cell system market, they have not released specific details on any system.

Is There a Fuel Cell In Your Future?

Despite the intense development efforts, commercially available turnkey residential fuel cell power systems are still almost two years away. Considering the rapid pace of development, there may be substantial changes in the technology even in this short time.

Developers are forming relationships with utility companies and other investors to facilitate development and product launch. The electric companies, not wanting to lose out to a new competitor, are keenly interested. The gas utilities, seeing a huge new potential market, are likewise attentive. And the fact that industrial giant General Electric is involved is a sure sign that this industry will likely not go away. What does this all mean to those already involved in the renewable energy movement?

Legitimization

As onsite-produced power becomes commonplace, life will no doubt become easier for all RE users. As utility companies begin to routinely connect fuel cell units to the grid, it should be a lot more difficult for them to discourage wind and PV system connections.

We should pay close attention as laws are changed to accommodate this shift, and make sure no one gets left out. Costs for many parts already used in renewable energy systems—inverters, for example—could become much lower due to mass production as fuel cell systems proliferate.

Opportunities

As this technology blossoms, it will be full of opportunities for those currently involved in the renewable energy industry. Readers of this magazine have already solved many of the problems that residential fuel cell developers are just starting to discover. For example, I'm sure that fuel cell companies have a lot to learn about real world battery use.

As people become more accepting of off-grid life, sales of non-renewable systems to augment the new residential fuel cells should explode. I even expect that off-grid real estate values will increase substantially once this technology is popularly accepted.

Challenges

This new technology will provide exciting new challenges in the RE world. By their very nature, those currently involved in RE are inclined to be "early adopters" of this new technology. Many of you have already shown your willingness to experience the hardships (and joys) of independent power. Both of the companies I visited acknowledged that present RE users would likely be among the first to purchase their products. I'm excited to see how some of you will solve the problems that will undoubtedly arise.

I hope to become a beta tester for one of these new systems when they are ready for residential testing. If I'm successful, I promise to share my experiences with you. In the meantime, I am planning to install a wind turbine to meet my immediate power needs, and eagerly wait to see if the promise of residential fuel cells becomes a reality.

Access

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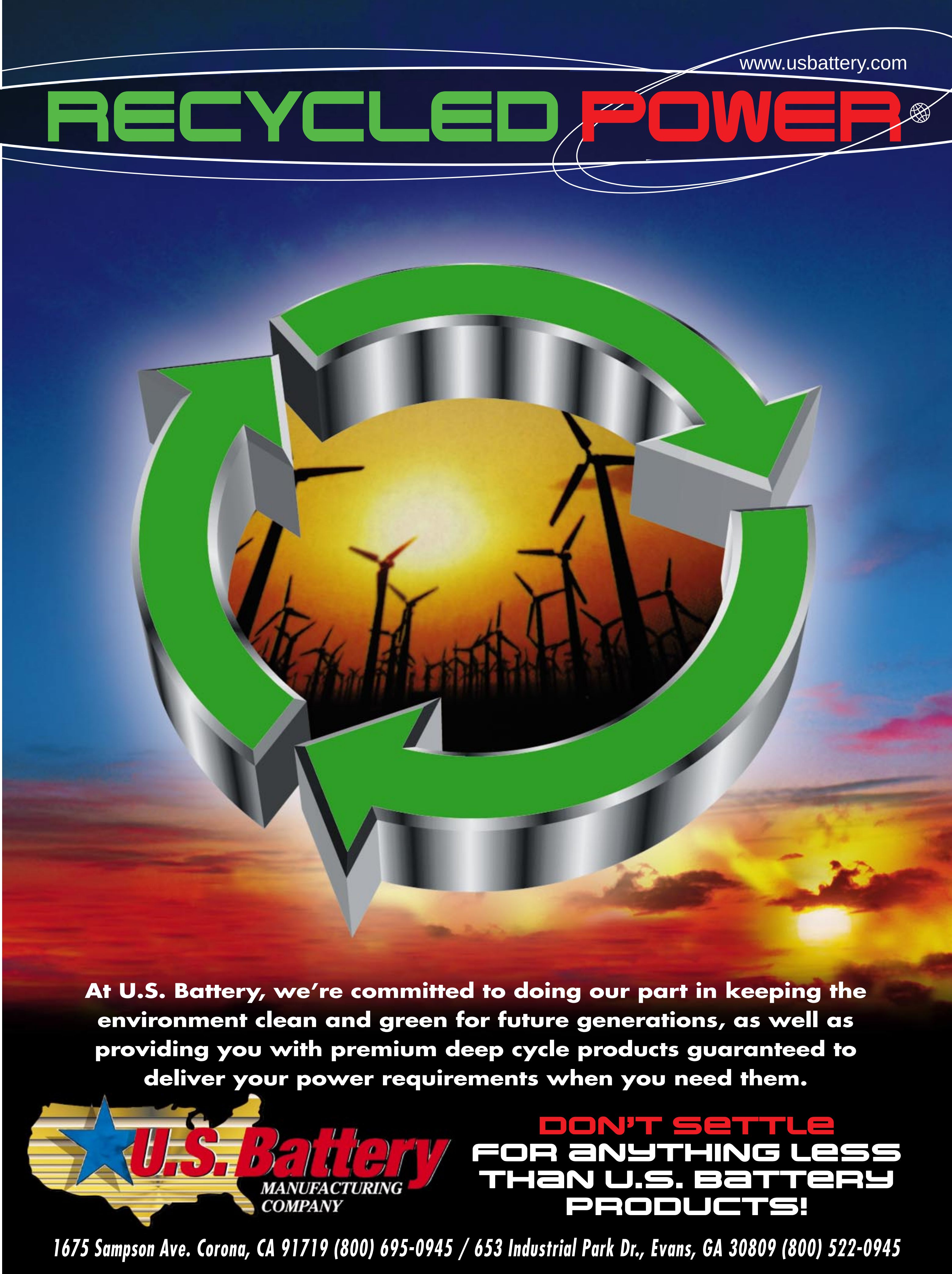
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SOUTHWEST WINDPOWER

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Experiments With Solar Hot Air Collectors

Ralf Seip

The solar collector installed outside the basement workshop.

I have been interested in alternative energy sources since about 1985. At that time, I was experimenting with solar-powered radios and battery chargers. Today, about 15 percent of the energy my family consumes is generated by a 240 watt photovoltaic system, with larger generating capability expected in the future. The latest addition to our solar energy system is a solar hot air collector.

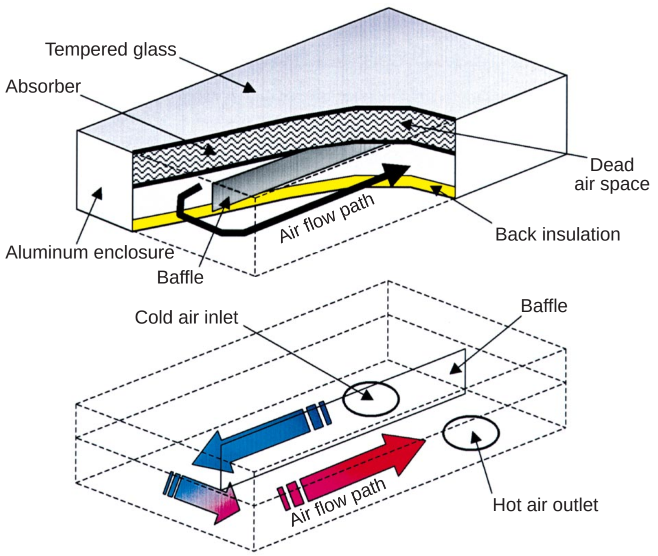
For years I have been wanting to experiment with a solar heating system to reduce winter heating bills, and a solar hot air collector seemed the right place to start. These collectors are simple because air is the heat transfer medium. This means that the glycol loops, heat exchangers, valves, and pumps commonly found in liquid collector systems are not needed.

The application of solar hot air collectors is slightly different than liquid collectors. Air collectors are typically used for space heating, while liquid collectors are typically used for water heating. Through the proper use of heat exchangers, however, either system can be used to heat water or air.

Collector Basics

Solar hot air collectors are simple and reliable. Cold air is drawn through the collector with a blower. It is heated as it comes in contact with an absorber plate exposed to the sun, and then returned as hot air for heating applications. The collector contains no moving parts, and is typically constructed of an aluminum frame, insulation on the back and sides, and tempered glass on the front. A black absorber plate is located between the glass and the back insulation.

Figure 1: Basic solar hot air collector and operation.



These collectors are of the single glazing/dead air space design, since some air is trapped between the absorber and the glazing. The absorber warms up when exposed to the sun, and some of this heat is transferred to the air between the absorber and the back insulation. Some absorber plates have dimples that create turbulence in the air, to better transfer heat to the air. Figure 1 shows a typical solar hot air collector of the single glazing/dead air space design.

System Description

The solar hot air collector system described in this article is used to warm up my basement workshop. Eventually, it will be used to warm up the living room located above the workshop through the existing forced air furnace ductwork. For the initial tests and evaluation period, I wanted to keep modifications to the house and existing ducts to a minimum.

The system consists of a 1.2 by 2.4 m (4 x 8 ft) Sun Aire solar hot air collector sold by AAA Solar, several insulated 15 cm (6 in) diameter ducts used to transport air to the collector and back to the workshop, a low-power fan to force the air through the collector, and a temperature control circuit that turns the fan on and off as required.

Collector

The collector faces south and is mounted on a simple but strong stainless steel structure, at an angle of 55 degrees. I assembled the structure out of 1.2 and 1.5 m (4 and 5 ft) lengths of slotted steel bars, available at local hardware stores. As a rule of thumb, to maximize the heating capability of the collectors in the winter months, they should be tilted to an angle equal to your location's latitude plus 15 degrees.

The structure is located close to the basement wall and is weighted down by 110 kg (243 lbs) of gravel. This temporary arrangement has survived wind gusts over 110 kilometers per hour (70+ mph). Eventually, I hope to anchor the structure properly to the concrete slab on which it now sits. The photographs show the collector and mounting structure. The collector is of the single glazing/dead air space design described previously, and its absorber plate is dimpled for higher transfer efficiency.

Fan & Ductwork

An insulated (R-4) flexible duct about 3 m (10 ft) in length transports cold basement air from the cold air inlet to the collector. I used aluminum tape on all duct joints to ensure an airtight seal. A small 14 watt AC muffin fan is able to push about 1.7 m^3 per minute (60 cf/min) of air through the collector. The collector heats the air, which returns to the basement through a similar duct and exits through the hot air outlet.

Muffin-type fans are typically not well suited for pushing large volumes of air through long ducts. Squirrel cage blowers (centrifugal blowers) are better at this task. The lowest power squirrel cage blower I found consumed 45 watts. The muffin fan seems to be adequate for this installation, as will be seen from the measured temperature increases and computed efficiencies later.

To keep house modifications to a minimum, the ducts enter and leave the basement through a window. I built a custom plywood/insulating foam/plywood panel that fits inside the open window frame and holds the ducts, fan, and circuit in place. I fastened the panel to the window frame with screws and used foam weatherstripping to prevent cold air from seeping into the house.

It is important to locate the hot air outlet above the cold air inlet, and the collector surface below both. This way, the fan is not working against the natural tendency of warm air to rise. It also transfers the colder workshop air to the collector first, and warmer workshop air does not get cooled down by the colder collector at night. The result is a more efficient system that does not require the addition of a backdraft damper to prevent nighttime cooling through the collector.

If such an arrangement of collector and duct exits is not possible (such as in rooftop mounted systems), a

Back of the solar collector showing part of the support structure, as well as insulated cold and hot air ducts.

Insulated duct adapter panel, showing the fan in front of the cold air inlet (lower right), the hot air outlet (upper left), the temperature control circuit, and the dual thermometer.

backdraft damper will be needed to prevent nighttime cooling. Notice the similarities between these guidelines and those for thermosyphon liquid-based collector systems. AAA Solar Supply's *Solar Design Catalog* has excellent installation guidelines for rooftop-mounted solar air collectors.

Temperature Control

The fan is controlled by a simple temperature control circuit. I designed and built the circuit over a weekend, and it is described in detail in the sidebar. For the circuit to operate properly, one thermistor needs to be exposed to the cold workshop temperature (close to the cold air inlet), and the second thermistor needs to be placed inside the hot air outlet.

System Cost

Item	*Cost*
4 x 8 ft solar hot air collector	$415
Shipping and crating charges	$185
Mounting structure	$80
Ducts, adaptors, and insulated panel	$40
Temperature control circuit and fan	$25
Dual-monitoring thermometer	$15
Total	$760

Warm air rising from the collector through the duct will reach the second thermistor, increasing its temperature. Once its temperature is approximately 2°C (3.6°F) warmer than that of the cold air thermistor, the fan is activated automatically and the system starts pushing warm air into the room.

To collect the temperature information presented in this article, I installed a digital thermometer capable of measuring two temperatures simultaneously. I used this thermometer to measure the workshop temperature and the temperature of the warm air coming from the collector after it had travelled through the 3 m (10 ft) return duct. The thermometer and temperature circuit can be seen in the photo to the left.

System Cost

The main components of the system and their cost are listed in the table. Notice that the total system cost is similar to that of about two typical photovoltaic modules. Sadly, crating and shipping charges are a large percentage of the overall system cost.

System Performance

To best illustrate the operation and effectiveness of the solar hot air collector, I measured typical air inlet, air outlet, and outside air temperatures for several days in intervals of 30 minutes. This allowed me to compute the power and energy produced by my system, as well as its efficiency. It also allowed me to give quantified answers to questions such as "Does the basement feel warmer now?" and "Does the system pay for itself?" It is interesting to see that solar energy does definitely impact the bottom line.

To perform these computations, it is necessary to introduce several physical constants, system-specific constants, and the underlying simple heat energy equation.

Physical Constants & Conversions

Specific heat of air (constant pressure, and 27 to 47°C):

$$c = 1.007 \text{ kJ / kg °K}$$

Density of air (at 760 mm mercury, and 40°C or 104°F):

$$d = 1.122 \text{ kg / m}^3$$

Average solar radiation S:

$$S = 1 \text{ kW / m}^2$$

Kilowatt-hour to kilojoule conversion:

$$1 \text{ kWh} = 3.6 \times 10^3 \text{ kJ}$$

System-Specific Constants

Collector area A:

$$A = 2.9 \text{ m}^2 = 31 \text{ ft}^2$$

Air volume v moved by fan:

$$\begin{aligned} v &= 60 \text{ ft}^3 \text{ / minute} \\ &= 1.7 \text{ m}^3 \text{ / minute} \\ &= 51 \text{ m}^3 \text{ / 30 minute} \\ &= 102 \text{ m}^3 \text{ / hour} \end{aligned}$$

Air mass m moved by fan:

$$\begin{aligned} m &= v \times d \\ &= 57 \text{ kg / 30 minutes} \\ &= 114 \text{ kg / hour} \end{aligned}$$

Heat Equation

Heat transfer rate H (result in kilojoules per hour):

$$H = m \times c \times (T_2 - T_1)$$

Heat transfer rate H (result in kW):

$$H = m \times c \times (T_2 - T_1) \div (3.6 \times 10^3)$$

Instantaneous efficiency e:

$$\begin{aligned} e &= (H_{actual} \div H_{max}) \times 100\% \\ &= [H \div (S \times A)] \times 100\% \end{aligned}$$

For this particular system, we use 2.9 kW for S x A, which corresponds to the area of the solar collector times the solar insolation. This is for times of maximum solar insolation only.

$$e = (H \div 2.9 \text{ kW}) \times 100\%$$

Notice that the heat flow rate H (typically expressed in joules per hour) is easily converted to kilowatts. The heat flow rate H depends on the specific heat c of the material (air in this case), the rate of mass transfer m through the collector, and the temperature difference (T_2-T_1) across the collector in degrees Kelvin (°K). Note that the calculation of H is a power (not energy) calculation.

Figure 2: Cold air inlet, hot air outlet, and ambient temperatures during a sunny winter day.

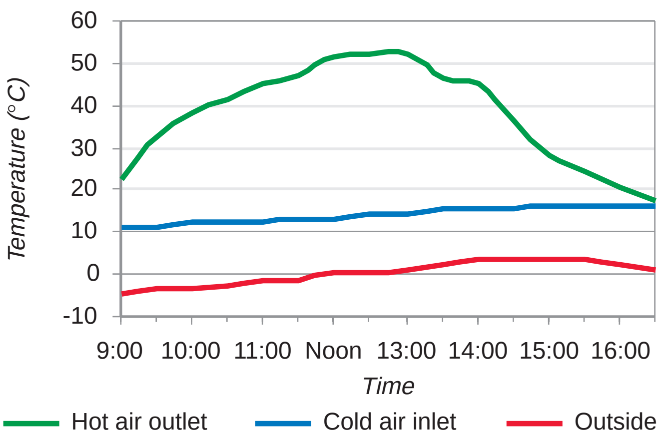
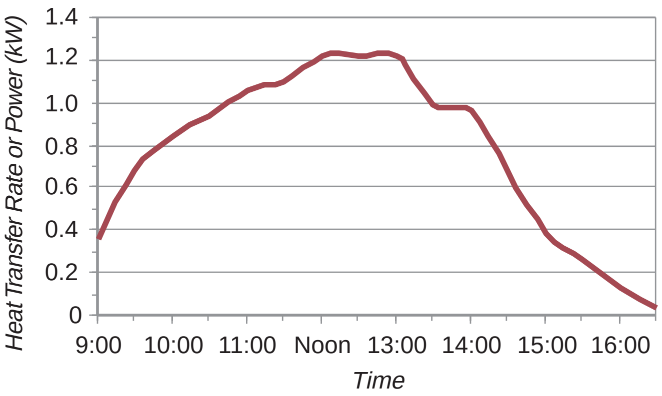


Figure 3: Energy produced during a sunny winter day.



By measuring both collector inlet air temperature (T_1) and collector outlet air temperature (T_2) and using the above equation, the instantaneous power added by the sun through the collector to the air in the basement can be computed. The energy (kWh) can then be calculated by integrating the instantaneous power (kW) over time, in hours.

Figures 2–5 show the measured temperatures and produced power for two days during the 1999 Michigan winter. Figures 2 and 3 show the measured temperatures and computed power during a nice, sunny winter day (outside temperatures of -5 to 3°C, or 23 to 37°F). The total energy produced by the solar collector during the day was approximately 6 kWh, raising the workshop temperature by about 5°C (9°F).

Figures 4 and 5 show the measured temperatures and computed power during a cloudy, overcast winter day (outside temperatures of -7 to -1°C, or 19 to 30°F). The total energy produced this day was approximately 1.9 kWh, raising the workshop temperature by about 2°C (3.6°F).

Figure 4: Cold air inlet, hot air outlet, and ambient temperatures during an overcast winter day.

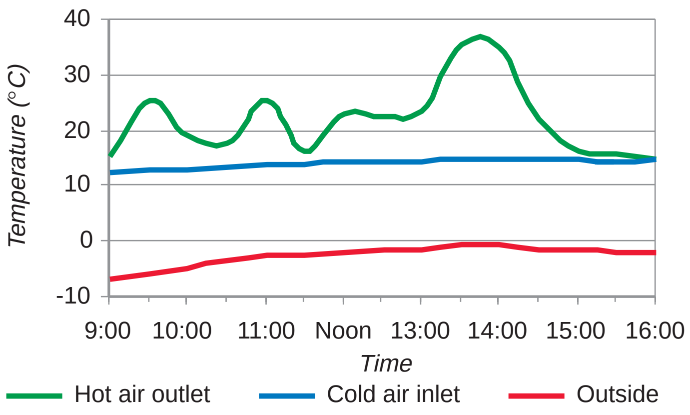
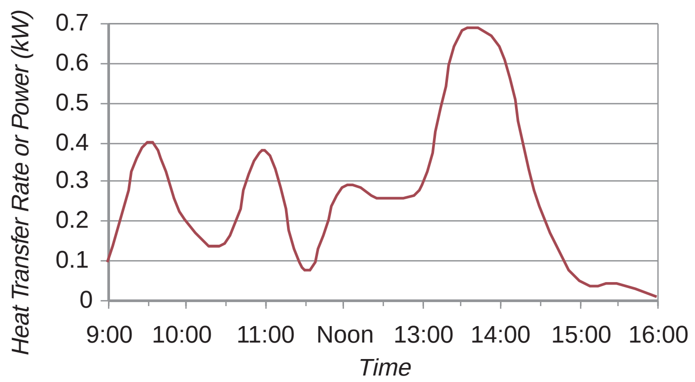


Figure 5: Energy produced during an overcast winter day.



Fan Control Circuit

Temperature control of the system is provided by a simple differential temperature sensing circuit. This circuit automatically turns the air circulation fan on when the temperature of the air at the collector output is warmer than the temperature of the air at the collector input, and leaves the fan off otherwise. The temperature difference needs to be about 2°C (3.6°F) and can be calibrated through R1 (see schematic). The fan is turned on and off through a 30 mA maximum coil current relay.

This setup ensures that the fan and collector are only used to add heat to a room, not to remove it. Two thermistors are used for this purpose: one mounted close to the cold air collector input (TR1), and the other mounted inside the collector hot air output (TR2). The schematic of this circuit is shown below. All the parts to build it can be found at stores such as Radio Shack.

The circuit consumes approximately 24 mW in the *off* mode, and 720 mW in the *on* mode, and operates at 24 V. The AC fan consumes 14 W when operating. The relay could be used to control a DC-powered fan, if available. Simply replace the AC power source and the AC fan with a corresponding DC power source (battery) and a DC-powered fan.

Calibrate the circuit by adjusting R1 until the fan turns on when a warm finger is placed on TR2. Then it will typically turn the air circulation fan on during a sunny winter day around 9:00 AM, and turn it off around 4:30 PM. The circuit also turns the fan off and back on during and after prolonged cloud covers on overcast days. This happens when the temperature of the air at the collector output drops below the temperature of the air at the collector input plus 2°C (3.6°F). This happened at around 11:30 AM on the overcast day detailed in Figure 4.

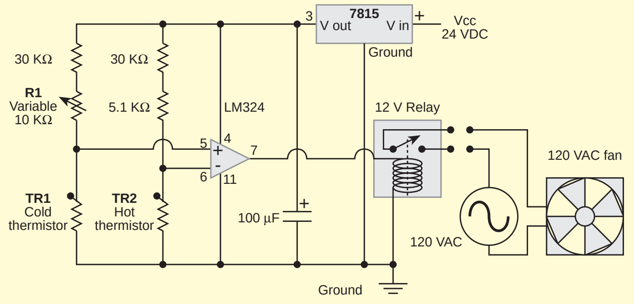
Since the hot air outlet is about 50 cm (20 in) above the cold air inlet, a large enough temperature difference is present as soon as the sun begins to warm the collector, resulting in proper and automatic circuit operation. Such circuits are commercially available for liquid-based collector systems, and are called differential controls. In those systems, a circulating pump is typically controlled by the circuit.

A possible improvement to the circuit would be to add an automatic absolute temperature switch. This switch would prevent the circuit from switching on when no heating is required because the room is already at the desired temperature. This feature would be helpful during warmer spring and summer days, when adding heat to a room would not be desirable. The present circuit needs to be manually unplugged at the beginning of spring and reconnected in the fall to achieve this operation.

Temperature Control Circuit Parts List

Qty	*Description*
1	7815 voltage regulator
1	LM324 operational amplifier
2	Thermistors (Radio Shack part number 275-248)
1	12 VDC relay, 30 mA max. coil current (Radio Shack part number 271-110)
2	30 KΩ resistors
1	5.1 KΩ resistor
1	10 KΩ adjustable potentiometer
1	100 µF capacitor
1	120 VAC muffin fan (or DC-powered, depending on the available power source)
1	Small circuit board
	Miscellaneous parts: wires, solder, connectors, etc.

Temperature Control Circuit Schematic



During the winter months, the basement workshop temperature hovers around 11°C (52°F). The installed collector is able to raise this temperature as much as 6°C (11°F) during sunny days. This results in a comfortable working temperature around 17°C (63°F).

The largest temperature difference measured to date between the air inlet and air outlet has been 45°C (81°F). This corresponds to a maximum efficiency of approximately 50 percent (114 kg/h x 1.007 kJ/kg °K x 45°K ÷ 3.6 x 10^3 kWh/J ÷ 2.9 kW x 100% = 50%). Even though this efficiency is respectable, the single glazing/dead air space collectors are supposed to be between 60 and 70 percent efficient. Currently, I am attributing the loss in efficiency to the long flexible ducts connecting the collector to the basement.

Typical temperature differences between the air inlet and air outlet are below 40°C (72°F). This seems to indicate that the fan that I am currently using in my system is pushing close to the right amount of air through the collector. But the maximum measured efficiency of this system at 50 percent is still below the 60 to 70 percent specified for these solar collectors. So I will be conducting measurements with higher-capacity fans and blowers to determine their effect on system efficiency. These experiments will have to wait until next winter.

Rewards

It is satisfying to feel the hot air streaming out of the hot air outlet during collector operation. It is also rewarding to be able to work in a warmer workshop, knowing that it is heated by the sun. I am assuming that we are lowering house heating costs indirectly by some small amount through workshop heating.

From a purely financial viewpoint, the savings are small. We currently heat our home with propane during the winter. One gallon of propane contains 90,000 BTUs, approximately 70 percent of which can be extracted in the form of heat. Furthermore, it takes approximately 3,410 BTUs to generate 1 kWh of energy. This means that 1 gallon (3.8 l) of propane can generate approximately 18 kWh of energy.

Remember that the described system generated 6 kWh during a nice sunny winter day, or the equivalent of 1/3 of a gallon (1.3 l) of propane. At current propane prices of US$0.80 per gallon, this amounts to savings of 27 cents per day in the best case! Such calculations are somewhat depressing, but it is important to keep the bigger picture in mind. This picture includes less reliance on fossil fuels, a reduction in atmospheric emissions, a positive feeling of independence, and great hands-on learning experiences!

My system is able to increase the basement workshop temperature as much as 6°C (11°F) during sunny winter days. It was easy to install, and coupled with the automatic temperature/fan control circuit, operates unattended. I measured its operating efficiency to be approximately 50 percent. While realized savings in heating fuel costs are small, I enjoyed installing this system and am happy knowing that my family has decreased its reliance on fossil fuels just a bit more. I am now tempted to explore the capabilities of solar hot air collectors for water heating, but that will have to wait!

Access

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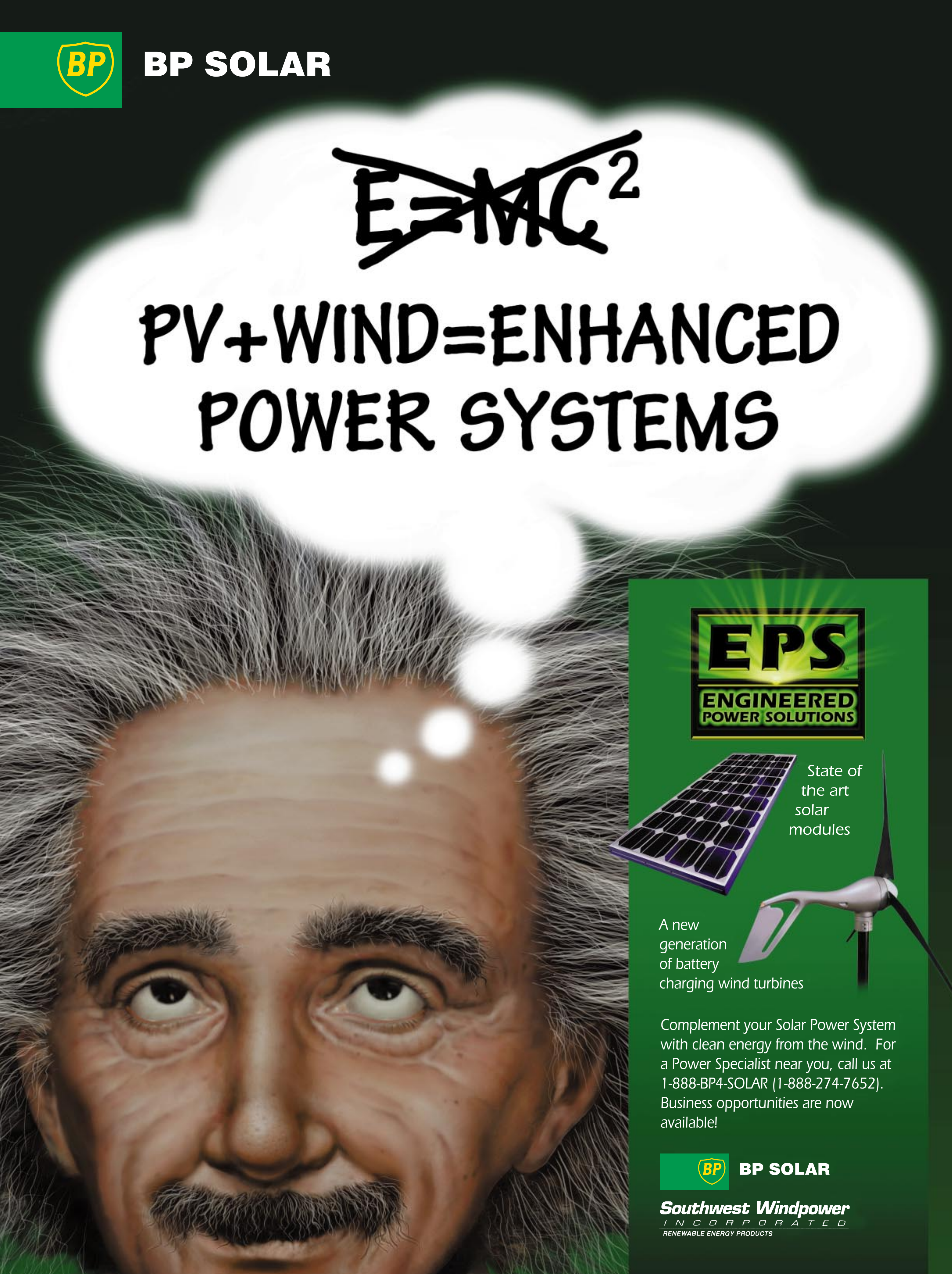
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Takin' It to the People:

The Education Station

Scott Ely

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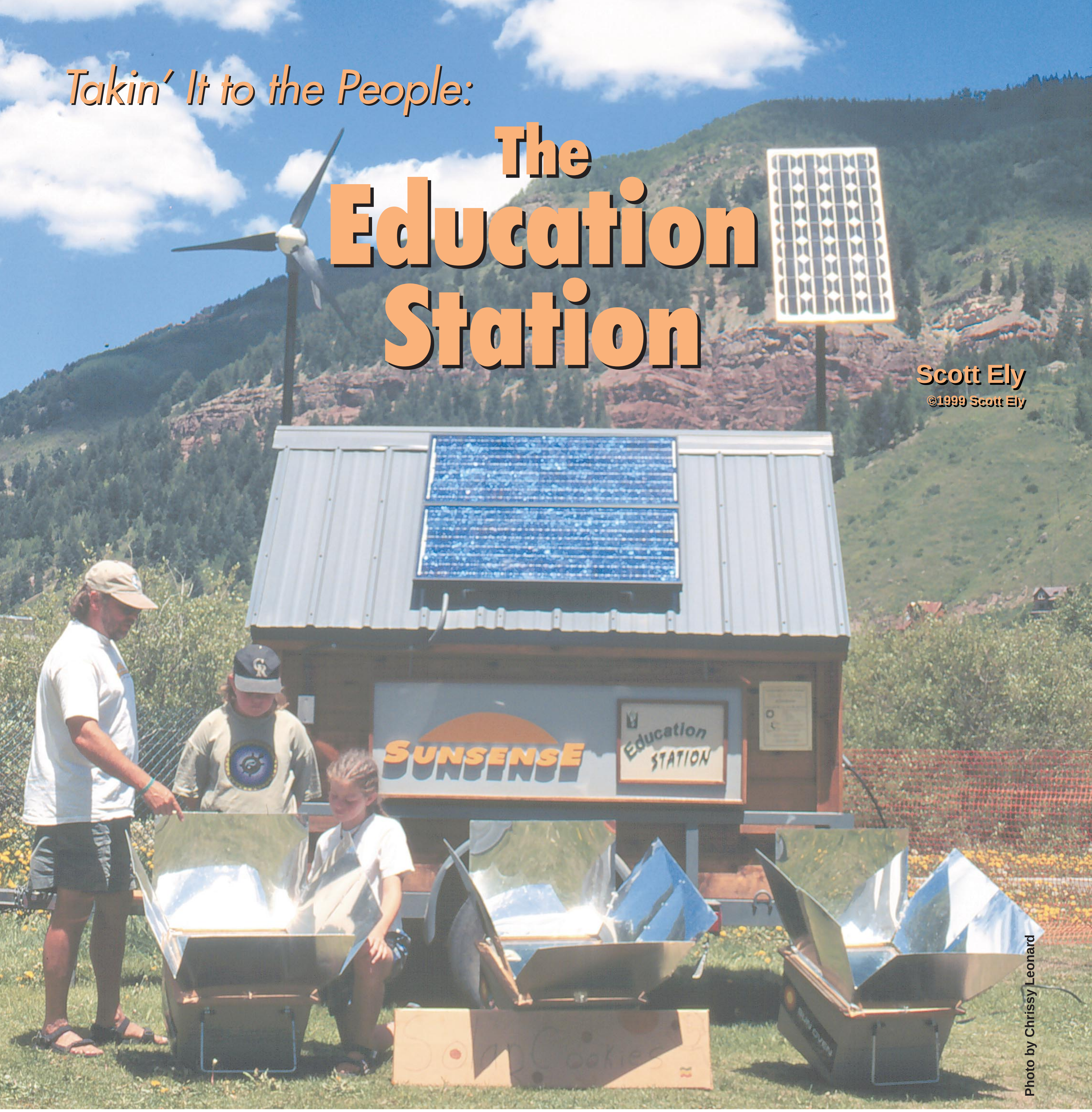


Photo by Chrissy Leonard

Scott Ely and future renewable energy supporters check out the E-Station.

Renewables are catching on! Everywhere we look there are signs of renewable energy (RE) becoming a mainstream technology. But believe it or not, there are still people out there who are totally unaware of renewable technologies. Perhaps they have been living in a cave, work in the fossil fuel business, or simply are not interested. Whatever the reason, RE *education* continues to present challenges for the industry and the public at large.

Owning an RE business immediately opened my eyes to the importance of education. Or perhaps my father, a professor, passed on the teaching gene to his son. Whatever the reason, it is clear to me that people who are well informed can better identify their needs, and develop a common sense game plan to address those needs. And if practiced throughout a population, education rewards people with a happier, healthier environment in which to grow and prosper.

I began to realize the importance of RE education back in 1990 while traversing the western slope of Colorado seeking out potential customers for my fledgling solar electric business, Sunsense. It seemed as though the opportunities were there, but the knowledge and familiarity with renewables was lacking.

So I tried to include some kind of RE display or demonstration in every business (and personal) activity. The Sunsense office was retrofitted with a solar electric system. I designed and built a small "power box" for providing electricity at the job site, using solar power to install solar power. We could also use the power box at various other functions for powering blenders, music, lighting, etc.

E-Station's vented battery box holds four Trojan T-105 lead-acid batteries.

The E-Station's control board slides out to become an indoor display in winter.

Then it hit me. Wouldn't it be nice if I could take renewable energy technology to the people rather than asking them to come to me? Fairs, festivals, workshops, seminars—any event could serve as a platform for the further education of the public about renewable technologies. Enter the idea for the mobile renewable energy education demonstration trailer—the Education Station, or E-Station. From PV and wind power to solar cooking, AC compact fluorescents, and even a solar powered bubble machine for the kids, the Education Station has been providing the public with a working demonstration of renewables for almost five years.

The current E-Station and its "offspring" are the result of an evolutionary process. From a simple, sales-driven RE demonstration to a sleek, stand-alone showpiece, the E-Station continues to evolve and expand. The original idea has blossomed into a new challenge—to design and build a fleet of portable RE education trailers, one for every region of the country.

Phase One—From Mind to Matter

The original intent of the Education Station was primarily as a marketing tool. In the early years (1990-93) of Sunsense, I would visit a potential client armed with a couple of different solar panels, a charge controller, an inverter, and even a battery or two. I wanted people to see the equipment, touch it, and get an idea of how it goes together. I also brought photos of completed installations. This approach was very effective, but the people being enlightened to the wonders of solar electricity and renewables were the people who already had an application in mind, and consequently had a genuine interest in the technology. I needed to figure out how to reach the average person.

Investing in a demonstration system seemed like a good idea. I had experimented with various displays and demos at energy fairs and festivals in the past—portable power box systems, water pumping

displays, even a Sun Frost freezer loaded with Ben & Jerry's Brownie Bars! All were fun learning tools and helped to get solar and renewables in front of people. The best, however, had yet to be built.

The first E-Station was born in 1994, and was designed to look like a house. The building sat on a utility trailer and had a sturdy floor, cedar siding, 2 x 6 rafters, and a metal roof. The entire structure was designed to be removable in order to utilize the trailer for other functions. Forklift access was designed into the floor system for easy loading and unloading. Two swing-out doors exposed the control board and battery box. Another access door on one side allowed the control board to slide in and out.

The control board featured a Trace 4 KW sine wave inverter and the corresponding APT power center. Four Solarex PV panels were roof-mounted and designed to charge eight Trojan golf cart batteries. All this on a five by eight foot (1.5 x 2.4 m) trailer rated at one ton (907 kg). What a load!

That first version of the E-Station made many stops around western Colorado, including visits to energy fairs, the Telluride Bluegrass Festival, our own Carbondale Mountain Fair, and numerous Solar Energy International classes. We could power up sound systems, tools, kitchen appliances, and security lighting. Perhaps the most fun was driving down the highway and having people pass the rig with thumbs up and heads bobbing spirited approval.

The initial success of the E-Station was just the beginning. With new RE products and concepts being introduced almost monthly, it was time to expand! The 1995 edition featured the addition of an AIR 303 wind turbine, an upgraded APT power center, and some new signage.

As the road show continued, I really felt that I was reaching people. The entire trailer made folks curious. Most people had either seen solar panels in high-profile applications (highway construction warning lights, billboard lighting, roadside weather stations, etc.) or they knew someone who had installed a system on a cabin or RV. They wanted to know more about how solar panels produce power and what other applications exist.

We helped people with everything from the correct pronunciation of "photovoltaics" to identifying the various components in a typical system. We helped to clarify concepts such as the flow of electrons from solar panels through controls to the batteries and the subsequent transformation of DC to AC power through the inverter to the AC loads.

The wind turbine was another big draw. People noticed the turbine spinning away and wanted to know how much power it was producing and the associated cost. Metering inside the E-Station showed the current being generated by either the solar panels or the wind turbine or both! We handed out product literature and made recommendations on local contractors proficient in renewables.

With all this interest in solar and renewables, I felt we needed to expand yet again. There were questions regarding other RE technologies and applications such as water pumping, microhydro, and solar cooking. We also wanted to include some fun things for the kids.

The problem with this expansion was the inherent weight of the E-Station. With a solid structural framework and a typical RE system design (a fairly large solar array, battery bank, and 4,000 watt inverter), the E-Station was simply too heavy! How could we add more systems and get the weight under control?

Phase Two—A Lean, Mean Learning Machine

Those early years helped me realize that while the first version of the Education Station was effective, it was embryonic compared to its potential. A new E-Station needed to be built with the focus on education, instead of sales. The first order of business was a form of "lumber liposuction." We had to trim the fat in order to add more systems.

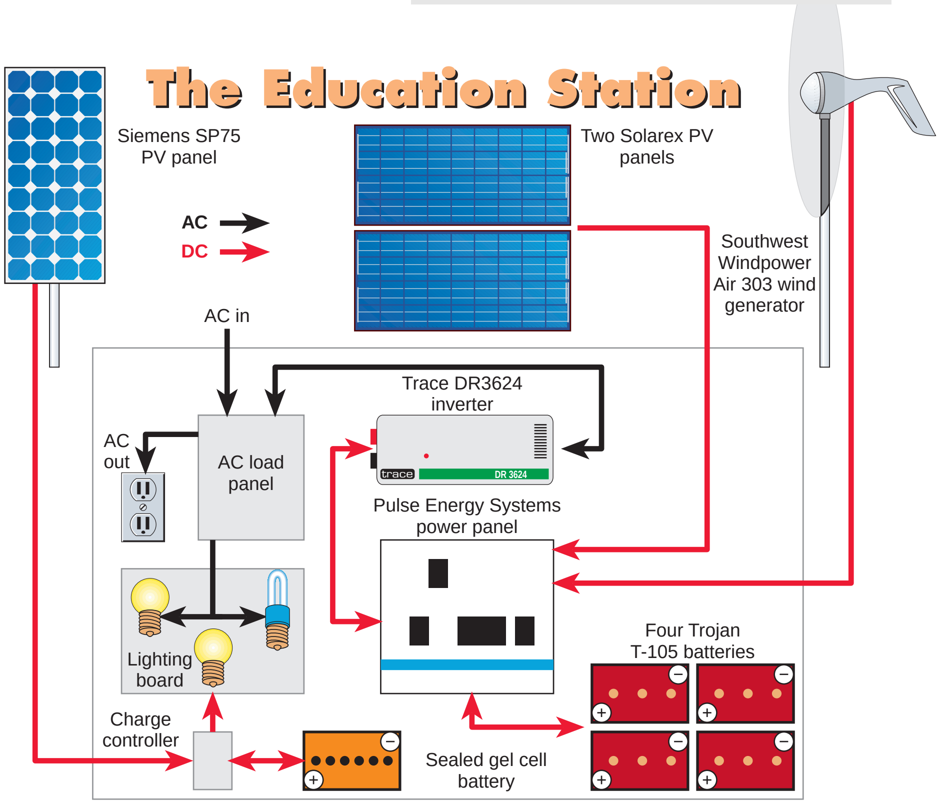
This second edition of the E-Station incorporated many of the original ideas. With design and building assistance from Mark Wolfe Webber of Wolfe Brand Construction in Carbondale, we created a lighter building with numerous attachments for various system displays.

The floor was still structurally sound. We kept the access slots for forklifting. Mark was able to locate some scrap cedar siding which we recycled into the building. The rafters and wall studs were downsized to two by fours, recycled where possible. The new access door was a lift-up section, providing shade and shelter from the weather. The overall dimensions decreased and the power system sizing was adjusted. All the components could be stored inside the structure for easier transport and the overall weight was still less than the original!

The PV system for this reincarnated E-Station included two Solarex panels (again roof-mounted), four Trojan golf cart batteries, the Trace 2.5 KW sine wave inverter and corresponding APT power center, and the AIR 303 wind turbine. One Siemens SP75 panel was top-of-pole mounted opposite the wind turbine to operate a water pumping demo.

Peripheral displays included a Burns-Milwaukee Sun Oven for solar cooking, and at some events the solar-powered bubble machine (special thanks to Ed Eaton at SEI). In addition, we had weathertight AC and DC receptacles available on the outside of the structure. Inside, we featured a comparative display of incandescent versus compact fluorescent lighting.

Armed with this high-performance mobile education unit, we again hit the road in the Summer of '96. The upgraded E-Station could now demonstrate more technologies to an ever-expanding group of people. The finely crafted structure was attractive by itself, but with the wind turbine cruising, water flowing from the solar pumping system, and the smell of fresh-baked cookies in the air, you can imagine the response!



Many of the people would stop for the same reasons as before—curiosity, basic information, even some RE techies with problems to solve. Some of the same people would return to report on their own system progress or to get updated information. And the kids loved it! They would watch and smell the cookies baking (usually standing directly in front of the oven) and chase the solar bubbles.

Some kids would even listen in on the conversations with their parents regarding renewables and the local political/social views on the subject. And perhaps the best part of it all was the genuine "Thank you!" we received from nearly every patron. The E-Station was pulling its weight!

Phase Three—Stand-Alone Mania!
The following year (1997) the Education Station continued to perform, energizing many of the same functions as in years past. In addition to these events, we added a natural homebuilding workshop and our Carbondale Fourth of July "Solar Potluck." All were great fun and the public interest continued to grow. I found myself working from sunup to sundown answering questions and demonstrating system operation. People would start asking questions before the entire display was even together!

Demonstrations included showing people the volt and amp meters as the solar panels and wind turbine would charge the batteries. We would shade the solar panel supplying power directly to the water pump and watch the water stream slow down, then speed up again when unshaded. We could watch the meters with a load turned on and see the power draw, or we could show the difference in power consumption between the compact fluorescent and incandescent lights. We would also show people the basics of programming a Trace sine wave inverter. Great stuff, but exhausting!

Phase three has changed the E-Station in a number of ways. The two Solarex modules remain on the roof connected to the four Trojan T-105s. The APT power center has been replaced by a Pulse Energy Systems PSC series power center, and the Trace SW inverter has given way to the lighter and more compact Trace DR3624. The AIR 303 still assists with the charging and the comparative lighting board still exists. The single Siemens SP75 now charges a 12 volt gel cell battery and demonstrates a straight 12 VDC system. In sticking with the original theme, we can now show people roof mount vs pole mount, polycrystalline vs single crystal panels, flooded vs gel cell batteries, and 12 and 24 VDC vs 120 VAC power. A lot of information in a relatively small package!

Growing Wings
In addition to these basic system changes, documentation has been upgraded. The Education Station has grown "wings." These wings are wooden placards displaying information on the E-Station itself along with basic PV information and photos of actual installations.

The "information wing" includes a system schematic for the E-Station; an explanation of system operation, components, and concepts; and a Q&A section. The "photo wing" contains a photo display of various strategies for PV mounting, battery boxes, controls, inverters, and complete system layout. The idea, of course, is to allow people to look at the information and the components without any pressure.

Most folks (myself included) tend to drift away from displays where someone is ready to jump into a long-winded explanation or sales pitch. The wings provide a user-friendly approach where people can relax and take in as much as they want. Should questions arise, they can read through some of the information and look at the photos until someone is free to speak with them.

The other major upgrade to the current E-Station is the addition of stand-alone satellite displays. Still in the development stage, these displays are designed to provide additional information on other RE technologies and applications.

Each stand-alone display has a base structure on which system components are mounted. Again, we have employed the "wing" strategy to display information. The wings are attached to the sides and fold up for storage and transport. Speaking of transport, some parts of these satellite displays can fit inside the storage area of the E-Station, while the rest of the parts must ride in the back of the truck that is towing the trailer. Each peripheral display is reassembled on site and stands close to the E-Station.

People can work their way around each display and the E-Station at their leisure. We have developed one display each for solar cooking (rotating base, storage, and info wings), solar water pumping (support structure, acrylic tube, sub pump, panels on tracker, and info wings), and microhydro (turbine, "dummy" batteries, diversion load, penstock, and info wings). These peripheral displays allow the entire package to be spread out so that more people can participate.

What Price Education?

The Education Station has been through many changes, and changes often cost money. New, upgraded components and expanding system demonstrations have increased design, installation, and presentation costs over the years. So how much for one of these beauties?

The cost of the first version of the E-Station was about US$8,500. Today, with the peripheral displays, etc., the cost is closer to US$12,000. These figures are for the materials and equipment; not included are the countless hours of design and construction. But don't be deceived by the price tag. Much of the design and installation of these systems has been accomplished through class projects at Solar Energy International. So the Education Station begins educating right from the get-go.

The trailer, still in use today, doubles as a snowmobile trailer in the winter when the E-Station is in hibernation. The trailer is also available for helping deliver equipment to job sites for Sunsense. The slide-in control board comes out in the winter and serves as a nice indoor display at the Sunsense showroom. The forklift access allows us to lift the entire structure off the trailer and set it on pallets for the winter.

In addition, each system upgrade or expansion frees up the old equipment for use in other demonstration projects, or it becomes available for sale. Since we use standard rather than custom equipment, resale is not a problem. These multipurpose tasks and recycling of system components make for a very cost-effective package.

Someone once said, "If you think education is expensive, try ignorance." Spending little or no money on RE education fosters the apathetic mindset which has the potential to slowly erode the planet. Remember that this system—this teaching tool—is an investment. The longer we wait to spread the word about renewables and resource efficiency, the harder our recovery from the consequences.

E-Station—The Next Generation

As the renewable energy and sustainable technology markets heat up, the need for reliable information and education is reaching a critical stage. I've seen the Education Station through its metamorphosis. Now I feel the need to progress even further in educating and interacting with the public regarding renewables and other resource efficient technologies.

The Education Station and its satellite systems will carry on the mission of public education. With this in mind, we are investigating the formation of a non-profit educational branch of Sunsense. This non-profit entity would devote its time, money, and energy to continuing this effort. The Education Station would become the flagship for delivering the resource efficiency message.

The precedent has been set and the future looks bright. We encourage teachers, administrators, city/county/state officials, and others to get involved in the design and building of their own renewable energy demonstrations using any and all resources. The industry and the public are listening!

Access

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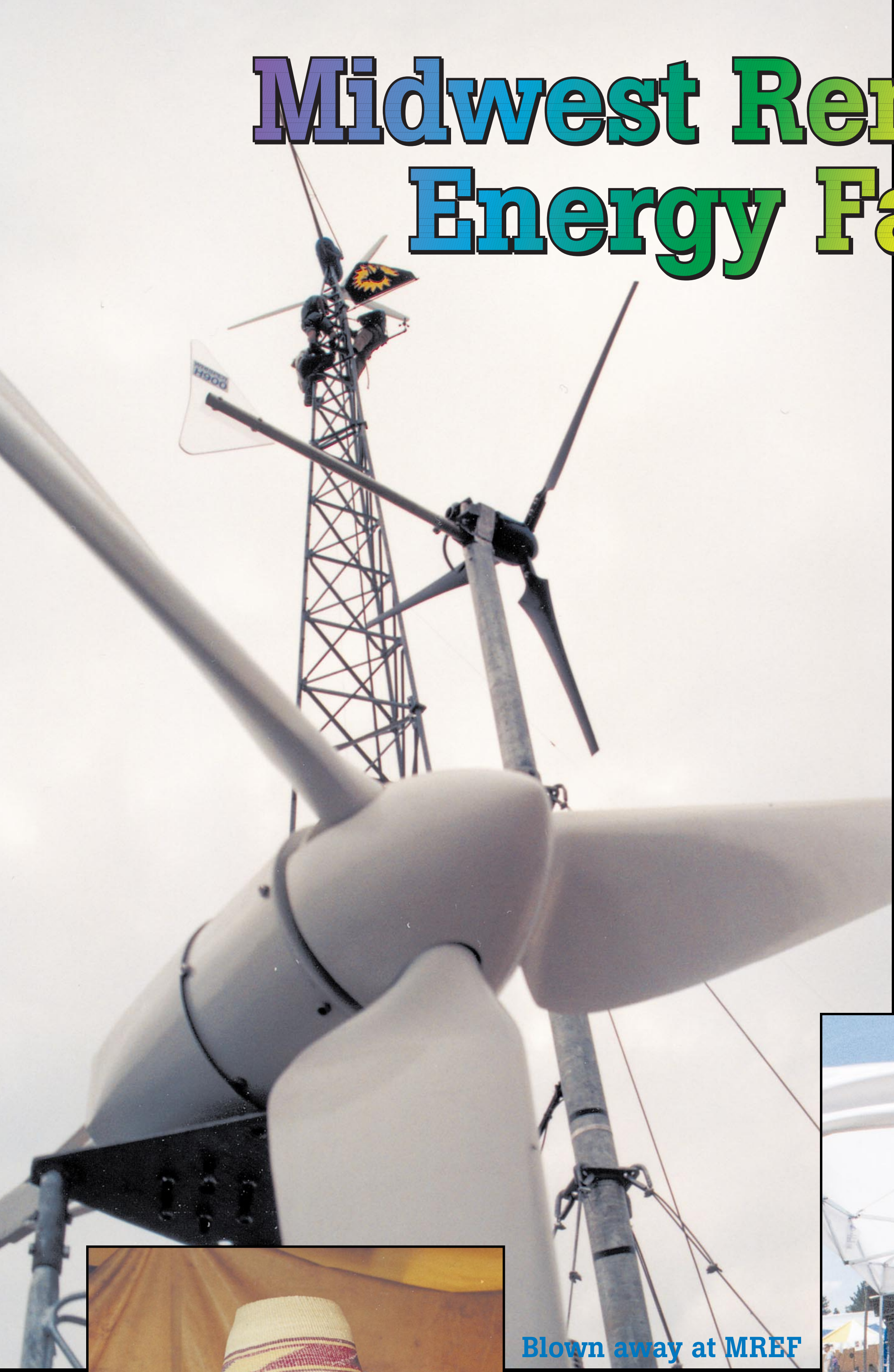
SOLAREX

full page

four color on negatives

this is page 49

Midwest Renewable Energy Fair 1999



It was a party indeed! Folks came from every state in the USA, and from many foreign countries. Over 11,000 of us spent June 18–20 in Amherst, Wisconsin attending the tenth anniversary of the best renewable energy extravaganza in the known universe.

This was the biggest MREF in history—more attendees, more RE businesses displaying their products, more workshops, and best of all, more fun. This year's keynote speaker, Alan Weisman, author of *Gaviotas*, gave a presentation to a packed house of over 2,000 people. Three days of non-stop RE talk filled us up with new information and perspective from old and new friends in the industry. Naughty solar guerrillas even hoisted their flag on the main wind genny's tower. Don't ask us who they were—we can't say....

Blown away at MREF

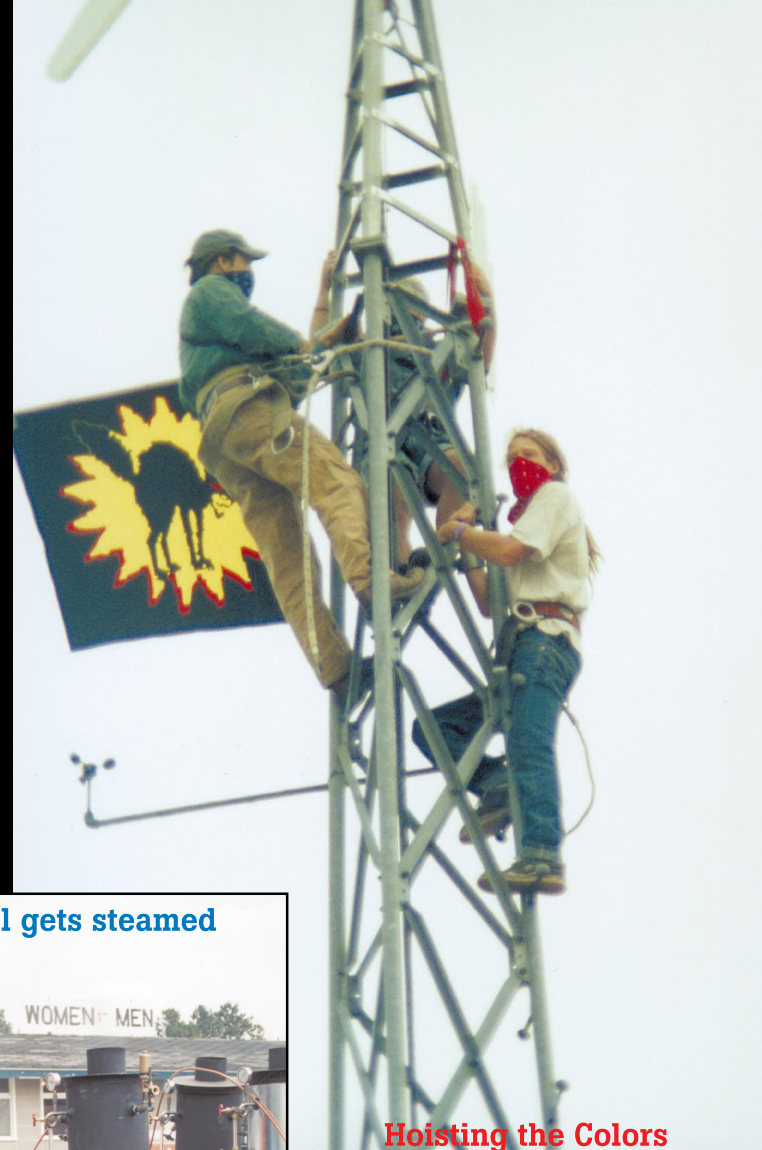
Jeff Green of IRENEW

Kelly Larson discovers cob

If you were lucky enough to attend the festivities at MREF '99, then we hope these pictures will bring back wonderful memories of the fine time we all had. If you missed this fair, then let these pictures encourage you to attend next year. At ten years old, MREF is just hitting its stride!

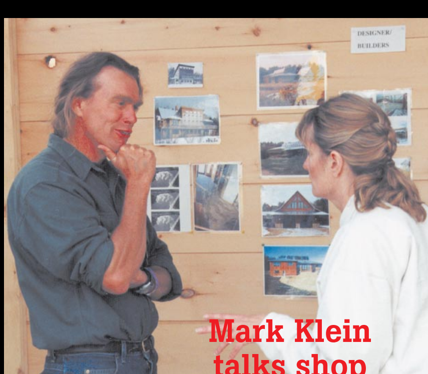
Where to?

Chris Molello with goodies



Hoisting the Colors

Skip Goebel gets steamed

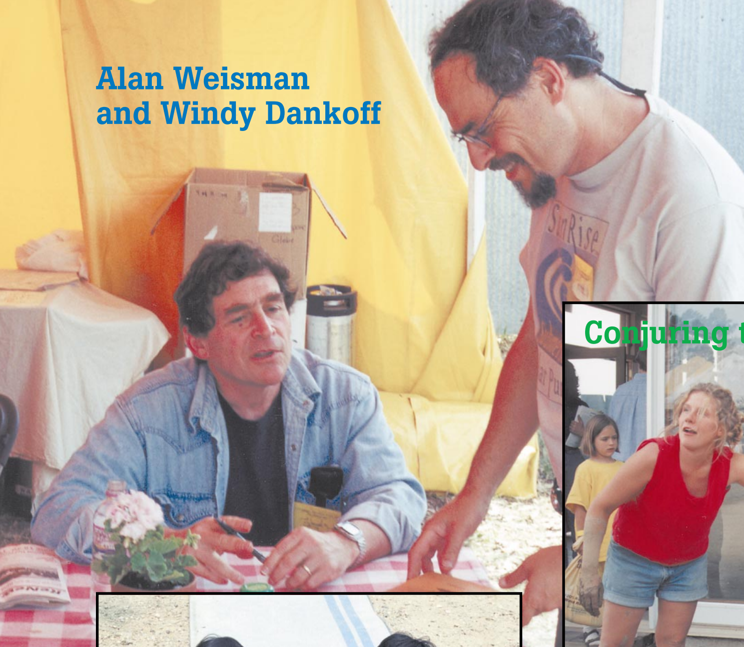


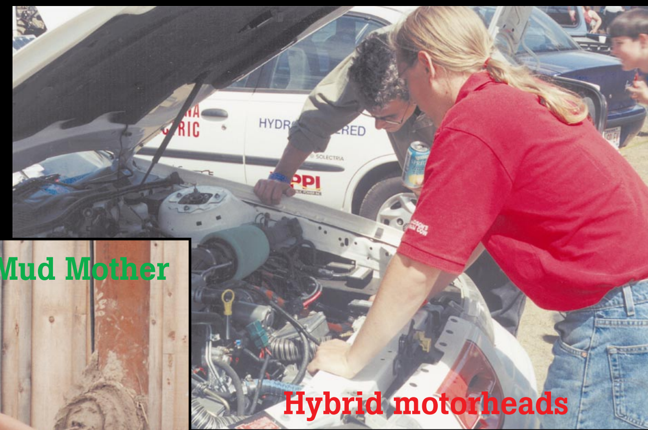
Mark Klein talks shop

Model Home—a hands-on showcase

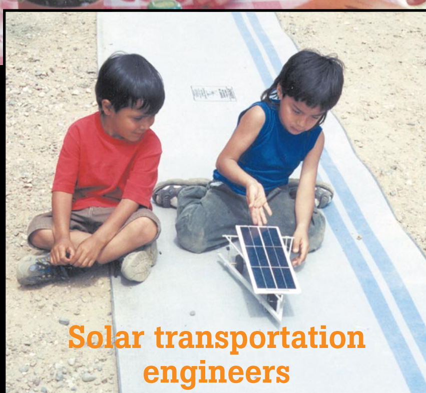
Cordwood construction in progress

Photos by Joy Anderson, Ben Root, Dan Lepinski, and Richard Perez


Alan Weisman and Windy Dankoff


Hybrid motorheads


Conjuring the Mud Mother


Solar transportation engineers

The Midwest Renewable Energy Association, POB 249, Amherst, WI 54406 • 715-592-6595 Fax: 715-592-6596 mreainfo@wi-net.com www.the-mrea.org

Electric rod

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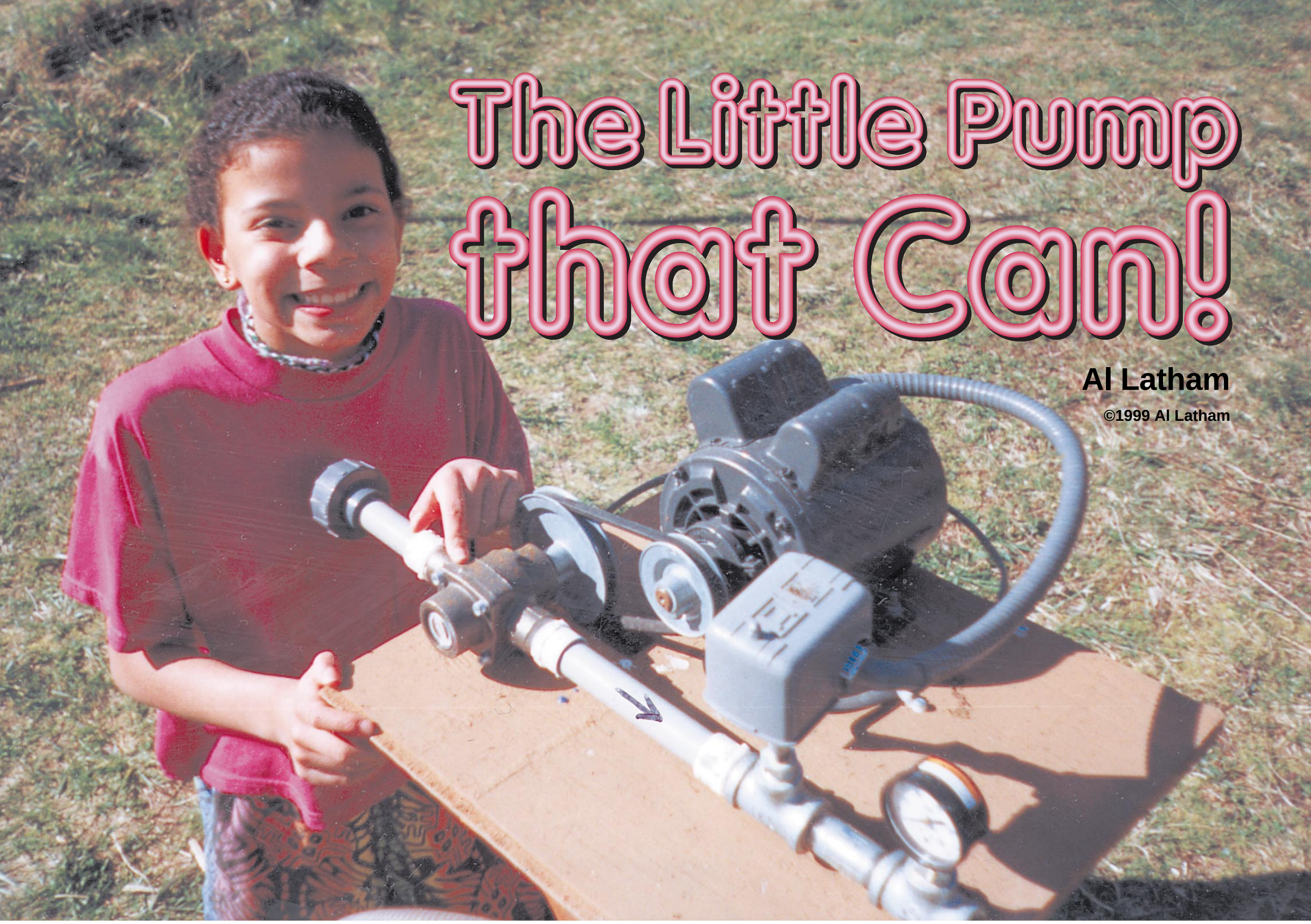
The Little Pump that Can!

Al Latham



Assistant Irrigation Engineer, Elena, with the home-built surface pump that can provide 6 gpm at 30 plus psi.

For years we had been using a gasoline-powered pump to irrigate the garden. Pumping enough water with our solar electricity had been a fantasy for years, but was not a high priority out here on the trailing edge of technology, as long as the gas engine would start. When the gas engine finally breathed its last, the solar-powered irrigation pump project jumped high enough on the list to get attention.

Our 12 foot (3.7 m) deep well is down in the trees, 400 feet (122 m) away and 12 feet (3.7 m) lower than the garden, solar panels, and battery bank. Water level in the old well fluctuates from ground level to negative 10 feet (-3 m). There was a good water distribution system of 1 1/2 inch (38 mm) pipe set up for the existing (er, now non-existing) gas pump.

The Problem and the Choices

We ran 120 VAC power from the Powerstar 1,300 watt inverter down to the well with #10 (5.3 mm^2) wire. It runs a Flowjet diaphragm pump, which fills the household cistern. We put in another run of #10 wire for the irrigation project because it was cheap and available. Trying to figure out how to run both pumps on one wire run—one on a float switch and one on a manual switch—was too much for me. The challenge was to find an irrigation pump that would run off a 1,300 watt inverter and 400 feet (122 m) of #10 wire, providing at least 4 to 5 gallons per minute (15–19 lpm) at 30 psi to the garden.

Our first option was to use another Flowjet pump to water the garden, since the one filling the cistern worked so well. But we wanted to run a drip irrigation system at 20 to 30 psi, which is beyond the power of the valiant Flowjet, I was told. Though it would pump water that far, it wouldn't pressurize. But I had to try it anyway and was amazed at how hot a little electric motor could become when asked to do more than it should!

Our second option was to get a bigger cistern and use gravity flow, or another booster pump to water the garden. But cisterns are expensive, and they become another maintenance chore.

Our third option was to buy a pump from one of the many fine dealers who advertise in *Home Power* magazine, but there didn't seem to be one that would fit our criteria. We needed something that would run off the 1,300 watt inverter, pump the slightly less than perfectly clean water from the well and/or nearby pond, and still be in our price range (as cheap as possible).

Our fourth option was to try to cobble up something myself, and that's what I did.

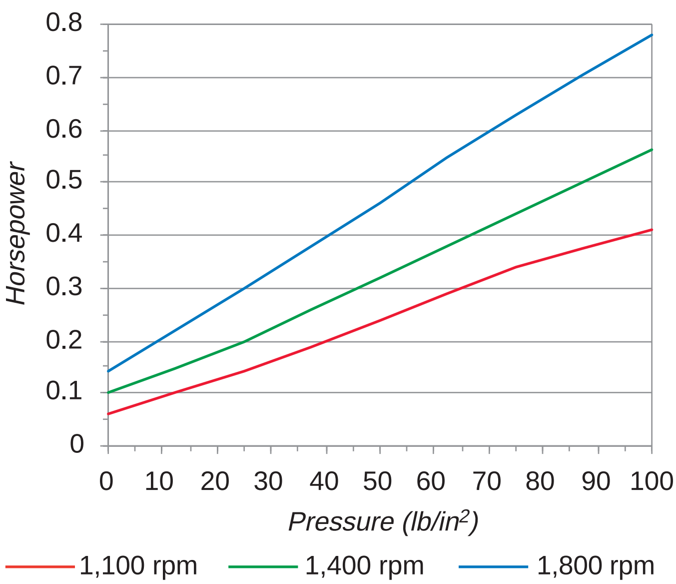
The Right Pump

Searching through the multitude of catalogs on hand, I came across a Hypro 4001N "roller pump" for US$114.75 in the Surplus Center catalog. The cast iron model is probably cheaper than mine, which has a Ni-Resist body, but I couldn't find one. The pump is designed for agricultural and industrial spraying and transfer of a variety of fluids. It was just right for the quality of water being pumped, and could provide 4 to 5 gallons (15–19 l) per minute with a 1/4 horsepower (hp) motor.

According to the literature that comes with these pumps, the rotary action principle requires no check valves while providing positive displacement characteristics. The pumps are rated at 100 psi for continuous operation. They are available with cast iron, Ni-Resist, or SilverCast™ body and rotor, 416 stainless steel shaft, sealed factory-lubricated bearings, and cartridge-type lip seals of Viton, Buna-N, or leather. The pumps also have versatile Super Rollers, which have the life of polypropylene and the chemical resistance of nylon.

These pumps are primarily used for livestock spraying, fertilizer application, and weed and pest control. They can pump wettable powders, light oils, aromatic solvents, etc. It seemed to me that if they would pump that stuff, they ought to be able to pump water. These pumps are also rebuildable, and the information that comes with the pump provides detailed instructions for repairs and rebuilds. For a good primer on pumps, see *A Graphic Guide to Water Pumping,* by Windy Dankoff, in *HP46.*

Hypro 4001N Pressure vs Horsepower

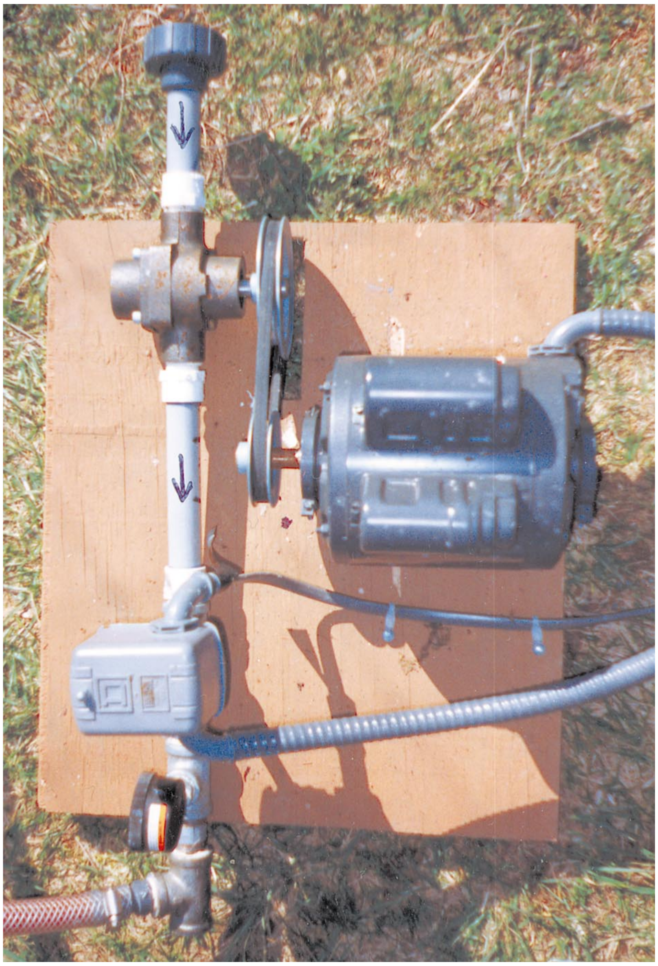


Graph extrapolated from Hypro pump performance table.

And Now For a Motor

I next consulted the bible of component putter-togetherers—the Grainger catalog. This resulted in an initial exclamation of "Woe is me!" (or words to that effect) when I saw how many amps a typical electric motor required. Five to six amps (full load) was the rating for typical 1/4 hp, 1,725 rpm motors. But the starting surge is considerably greater, and it would be much more than our 1,300 watt inverter could handle.

The pump, motor, and pressure switch assembly.



But Grainger also listed high efficiency capacitor-start motors for just a few dollars more. The 1/4 hp high efficiency motor (#4K700) has a measly 2.8 amp full load rating and cost US$118, only US$9 more than a normal watt guzzler! Huzzah! A motor that would run off the 1,300 watt inverter, 400 feet (122 m) of #10 (5.3 mm^2) wire, and a pump that would water the garden. Enough to make a solar nerd get weak in the knees....

Parts List

Description	*Source*	*Cost*
Hypro 4001N roller pump	Surplus Center	$115.00
1/4 hp high-efficiency capacitor-start AC motor	Grainger	$118.00
3 inch pulley	Hardware store	$2.85
4.5 inch pulley	Hardware store	$4.35
V-belt	Hardware store	$2.85
Precharged water pressure tank	Used	$15.00
Pressure switch	Hardware store	$15.00
"Y" type drip irrigation filter w/ 150 mesh screen	Hardware store	$20.00
	Total	$293.05

Getting the Pulleys Right

I cobbled together a spreadsheet and some graphs using the data from the pump performance sheet. Then I was able to evaluate pump output at various motor horsepower and pump rpm. This demonstrated that direct coupling the pump to the motor would not quite do what I wanted.

The 1/4 hp motor (the largest the inverter would handle) directly coupled to the pump would put out about 8.5 gallons per minute (32 lpm) at 17 psi, running at 1,725 rpm. To get more pressure would require changing the gearing by using different size pulleys on the pump and motor. A larger pulley on the pump would lower the pump rpm, resulting in a decrease in output (gpm) but an increase in pressure (psi).

This formula will determine proper pulley size:

$$\frac{\textbf{motor rpm}}{\textbf{pump rpm}} = \frac{\textbf{pump pulley diameter}}{\textbf{motor pulley diameter}}$$

In our case, a 3 inch (7.6 cm) pulley on the motor and a 4.5 inch (11.4 cm) pulley on the pump would turn the pump at about 1,150 rpm. My graph showed that this rpm would put out about 4 to 5 gpm (15–19 lpm) at 50 psi with a 1/4 hp motor. So, keeping the pressure down to 30 psi would create a system that would pump enough water for our needs and not max out the motor or inverter, at least in theory.

Will She Do It ?

When the pump arrived, I was a little concerned because it was so small (4 3/8 x 3 in; 11 x 7.6 cm). Could a little pump like that possibly provide all the water I needed? The only way to find out was to hook ‘er up and see.

To round out the system, we added a small pressure tank, a standard “y-type” 150 mesh drip irrigation filter between the pump and water supply, a foot valve, and a pressure switch set at 20 psi cut-in, 30 psi cut-out. Connections to the supply and distribution piping were made with 3/4 inch (19 mm) reinforced poly tubing.

Sun-Pumped Water!

We gathered all the components, put them together, and it was time to power it up. *It worked!* It pumped water and didn’t fry the inverter! But instead of 4 to 5 gpm (15–19 lpm), we got 5 to 6 gpm (19–23 lpm) of solar-powered water for all those thirsty plants just by opening a faucet. This is something that can only be truly appreciated by someone who has spent way too much time dealing with recalcitrant #@$%&!! gas engine-powered pumps!.

The system performed well all last summer operating a sprinkler. Even with the water level dropping about 10 feet (3 m) in the well, the pump was still able to provide water, though that is about the maximum suction head that can be expected.

Power consumption, according to a Bogart Tri-Metric battery monitor, is 17.3 to 19.0 amps (12 VDC), with a 22.6 amp starting surge. I tested it on our drip irrigation system, at approximately 140 gallons (530 l) per hour. With a ratio of 1.5 minutes running to 1.75 minutes off, the consumption was only 9.4 amp-hours per hour. With a pressure tank installed in the water line, the pump runs until the pressure reaches 30 psi. It then goes off until enough water is used to lower the pressure to 20 psi. If the pump were running all the time, it would use about 18 amp-hours per hour.

This summer we’ll experiment with some different pulley combinations to fine tune the system. We’ll also install that drip irrigation system, turning another solar-powered fantasy into reality.

Access

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Sources for parts:
Surplus Center, PO Box 82209, Lincoln, NE 68501-2209 • 800-488-3407 or 402-474-4055
Fax: 402-474-5198

W. W. Grainger, Inc., 100 Grainger Parkway, Lake Forest, IL 60045-5201 • 847-535-1000
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STEAM for the Homestead?

Skip Goebel

A 10 KW steam unit with a 400 amp maximum output at 30 volts.

Although steam power has been around for centuries, small-scale steam power has gone the way of the straight razor and a young girl's ability to make apple pie. We have become so spoiled on refined fuels and disposable goods that the skills necessary to be self sufficient have long been lost.

In days past, steam allowed people who were less than affluent to be producers of goods and services using the raw resources at hand. Today, steam is making a resurgence in the alternative energy field and promises to give other forms of alternative energy a run for their money. But steam power is no longer common. So education is necessary to give people the tools to make an educated choice.

Is Steam Right for You?

It is possible to generate electricity for the homestead with small-scale steam power. To find out if steam is right for you, answer these questions: How much wood do you want to cut? How much money do you want to spend? What are you going to do with all the heat? Do you have the savvy required to use an unrefined fuel?

How Much Wood Do You Want to Cut?

Most people say, "I have plenty of trees." What they don't realize is how much material handling is involved in using an unrefined fuel. A lot of elbow grease is needed to handle wood. And practically speaking, there is just not very much electricity in a stick of wood.

In typical steam systems, a small 500 watt genset may consume 20 pounds (9 kg) of wood an hour. A larger 10 KW AC powerplant uses 200 pounds (91 kg) of wood per hour, and if run constantly could consume a cord of softwood in less than two days. Now you see why coal and oil can look like viable options! Sure, you can get more by being more efficient, but that is a matter of cost, so...

How Much Money Do You Want to Spend?

A steam system is going to cost you between US$2 and $6 per watt. Used equipment is cheaper. Of course, the more efficient and automatic it is, the more expensive it is. You have to weigh the practicality against your capital investment. A lot of money can be saved by buying separate components, such as the engine and boiler, and assembling them yourself. This is hard work, but very satisfying—not to mention that you get a better understanding of your system.

A 500 watt system will cost you between US$3,200 and $4,000 new. Systems generating 10,000 watts or more will cost you about US$2 per watt. This may not be cost effective for you unless you have a use for heat, which is the main product of steam.

What Are You Going to Do With the Heat?

Even a 500 watt steam genset will produce 35,000 BTUs of useable heat in the steam exhaust. That's a lot of heat and it makes no sense to waste it. Whether or not you can use the heat is usually the deciding factor between a steam generator and a diesel generator. But if you have a use for large amounts of useable and controllable heat, no other form of alternative energy can touch steam.

A typical 10,000 watt steam genset can give you up to 1/2 million BTUs of controllable heat. In other words, steam will light the chicken farm and make heat to process the chickens too. Kiln drying, wood bending, food processing, refining, and chemical processes all are typical uses for steam heat. With steam, production processes are possible with raw resources. What you can do with the steam depends upon your knowledge and aptitude for mechanical things.

Do You Have the Savvy to Utilize Unrefined Fuels Like Wood?

We live in a time where the world is spoiled on the luxuries that refined fuels have to offer. Unfortunately, burning a solid and unrefined fuel requires full time attention. That is why there are refined fuels. Refined fuels allow the energy process to be automatically regulated and controlled—when it's on, it's on, and when it's off, it's off. Not so with fuels like wood.

There is an inherent danger when using a raw fuel and storing the energy in a boiler. This is not an insurmountable problem, but the operator must be educated in the process. It is best if the operator enjoys it. If you're into it, you're always finding ways to improve the process. Forget what your mom said and remember, "There is no shame in playing with fire."

Common Sense

When generating electricity, we usually overlook the efficiency of the load we plan to operate. Efficiency can mean big savings in your system cost—spend your money on efficient appliances and lighting first, and you won't be sorry. When it comes to individual components, you will find that there are specialists in each field. You will be time and money ahead if you deal with more than one vendor for a complete power system. Remember that application is the key and there is no "one size fits all" system.

Any form of alternative energy is going to require your time and attention. Buying from the electric company means they do all the material handling of the energy and you simply use it. Be prepared to spend money—serious money—on your energy production. And of course, be prepared to break a sweat now and then.

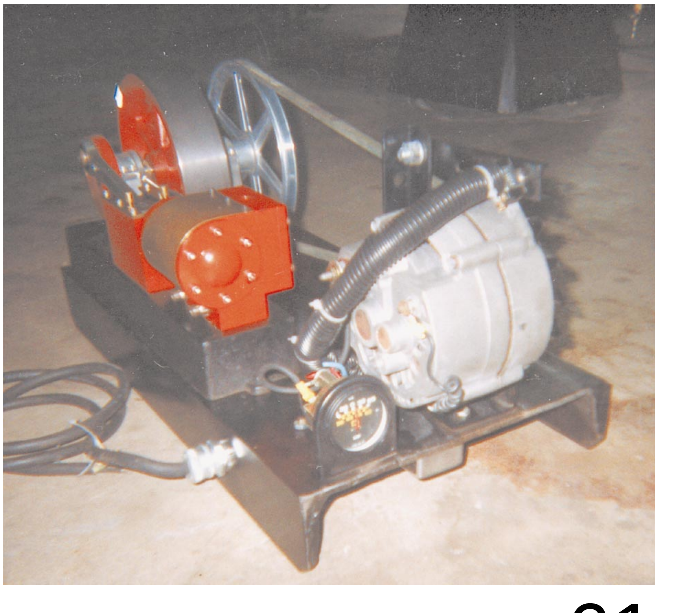
Generally speaking, the less automatic and more labor intensive your resource handling is, the cheaper it will be. You will have to decide for yourself just how far you want to go and how much you will spend to get there.

Look at the Costs

Steam has its own niche, as do other forms of alternative energy. Steam excels above the other common systems in applications requiring large quantities of controllable, useable heat. Steam also has an edge as far as capital investment. A small steam system of up to 5,000 watts will cost US$3 to $5 per watt. A system of 10,000 to 20,000 watts will cost US$2 to $3 per watt. Larger systems are US$1 or less per watt. And good quality used equipment costs much, much less!

Compare that with solar cells (US$9 per watt, system cost) and wind (US$2–4 per watt). So the gist of all this is that steam has the potential to be a dominant force in the home-based power production field. It is only a

A 500+ watt steam genset.



A 4 KW shop power system.

matter of time before the venture capitalists discover the next big investment in the alternative energy field. Steam is not for everyone, but it is definitely attractive to those who don't mind breaking a sweat and getting paid for it.

In Round Numbers

It takes 20 pounds (9 kg) of wood to produce 1 KWH. It takes 30 to 40 pounds (14–18 kg) of water converted to steam to produce 1 horsepower (hp) for an hour. An engine costs about US$1,000 per hp and a boiler the same. Commercial grade steam engines use sealed ball bearings and have few moving parts and therefore can last for decades with minimal maintenance.

It takes 1,200 BTUs to convert a pound (0.45 kg) of water to a pound of steam at 100 psi. Boilers are normally 50 percent efficient and engines 3 to 10 percent efficient. Most engines have between 30,000 to 40,000 BTUs per hp in the exhaust. Commercial type piston engines run between 600 and 1,200 rpm. They are capable of turning very slowly, and at 100 psi, give 15 to 20 footpounds or more of torque per hp. One steam hp is the same as one electric hp and up to three gas engine hp.

How To Do It

Step One: Get educated! Find a local steam guru to help you. Join a steam club in your area. There are over 5,000 steam engine clubs in the western hemisphere—chances are good that you're within an hour's drive of one. There are several publications on steam, but nothing beats talking to someone who has been there. Get the *Steam and Gas Engine Show Directory* to find a club near you. You might also contact a museum or local historical society.

Step Two: Get your financial arrangements in order. While this makes good sense for all alternative energy systems, it especially applies to steam. Steam is pretty intolerant of shortcuts.

Step Three: Determine what your needs really are. If all you want to do is make electricity and watch satellite TV in your air conditioned home, steam probably is not for you. Steam is the most labor intensive of all renewable energy systems and unless you have a use for all the heat you will create, it just isn't practical. In other words, *you're* going to be cutting the wood while someone else is enjoying the air conditioning.

Step Four: Scavenge or buy all the equipment you can get that utilizes steam. No, we are not talking electricity here. Rather, items like radiators, kiln dryers, wood benders, distillers and pasteurizers, all sorts of commercial food processors, sterilizers, etc. Many things you use in your everyday life are made with steam in one way or another.

Step Five: Educate the wife and kids about the health benefits and deep spiritual gratification that can only come from cutting and splitting wood.

Where to Find Help

Almost every factory and powerplant has a steam engineer floating around. Find 'em and buy 'em a beer or three. You will find that this highest form of the human race is quite amicable and willing to share their knowledge about steam. If you are too antisocial for this approach, consider joining the local steam club. See the Access section for a directory of local clubs and shows.

Another good way to learn is to attend steam school. Sensible Steam now offers three-day classes on steam as an alternative energy source. There will be several this summer. See our Web site for full information. Additionally, good reading on steam can be found in *Countryside Magazine.* These fine folks are serious about self sufficiency and they have their own steam system providing electricity and heat. Best of all, they designed it to their needs.

Steamed Eccentrics

I predict that steam will become to alternative energy what herbal medicines became to the pharmaceutical industry—not necessarily the only way to do the job, but one that is obtainable and works. While there are a lot of people who do not want to play with fire, there are lots who do. There is no way to describe the psychological satisfaction that comes from burning wood (and old bills!) and watching that energy being converted to mechanical motion. The heat feels good and the smoke is stimulating to those of us who are slightly eccentric. And after all, aren't most folks who dig alternative energy just a little eccentric?

Access

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What is a Charge Controller?

Windy Dankoff

A charge controller is an essential part of nearly all power systems that charge batteries, whether the power source is PV, wind, hydro, fuel, or utility grid. Its purpose is to keep your batteries properly fed and safe for the long term.

The basic functions of a controller are quite simple. Charge controllers block reverse current and prevent battery overcharge. Some controllers also prevent battery overdischarge, protect from electrical overload, and display battery status and the flow of power. Let's examine each function individually.

Blocking Reverse Current

Photovoltaic (PV) panels work by pumping current through your battery in one direction. At night, the panels may pass a bit of current in the reverse direction, causing a slight discharge from the battery. (Our term "battery" represents either a single battery or bank of batteries.) The potential loss is minor, but it is easy to prevent. Some types of wind and hydro generators also draw reverse current when they stop, but most do not, except under fault conditions.

In most controllers, charge current passes through a semiconductor (a transistor) which acts like a valve to control the current. It is called a semiconductor because it passes current in only one direction. It prevents reverse current without any extra effort or cost.

In some controllers, an electromagnetic coil opens and closes a mechanical switch. This is called a relay. It switches off at night, to block reverse current. As it turns on and off, there is an audible clicking sound.

If you are using a very small array relative to the size of the battery, then you may not need a charge controller. This is a rare application. An example is a tiny maintenance PV module that trickle-charges a battery and compensates for battery discharge in a parked vehicle but will not support significant loads. In this situation, you can install a simple diode to block reverse current. A diode used for this purpose is called a blocking diode.

Preventing Overcharge

When a battery reaches full charge, it can no longer store incoming energy. If energy continues to be applied at the full rate, the battery voltage gets too high. Water separates into hydrogen and oxygen and bubbles out rapidly. It looks like it's boiling so we sometimes call it that, although it's not actually hot. There is an excessive loss of water, and a chance that the gasses can ignite and cause a small explosion. The battery will also degrade rapidly and may possibly overheat. Excessive voltage can also stress your loads (lights, appliances, etc.) or cause your inverter to shut off.

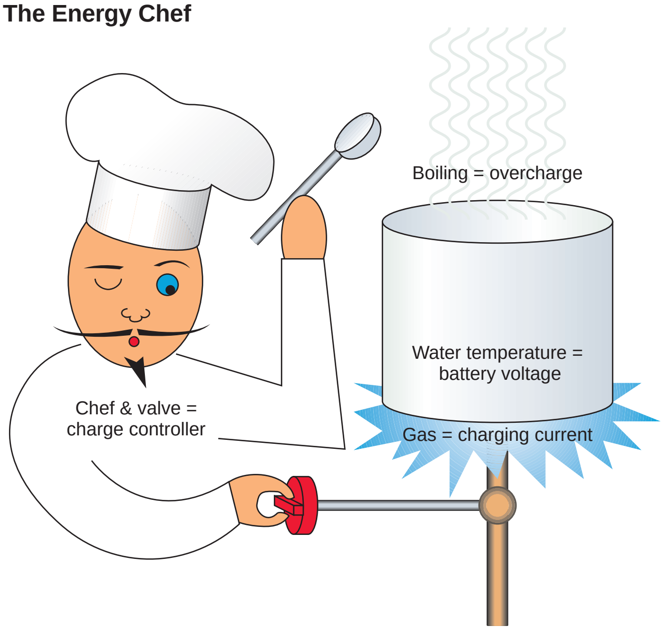
Preventing overcharge is simply a matter of reducing the flow of energy to the battery when the battery reaches a specific voltage. When the voltage drops due to lower sun intensity or an increase in electrical usage, the controller again allows the maximum possible charge. This is called voltage regulating. It is the most essential function of all charge controllers. The controller "looks at" the voltage, and regulates the battery charging in response. This can be illustrated by an analogy:

The Energy Chef is watching a pot of water on a gas burner, which is fed by a tube coming from the sun. He has one hand on the gas valve. He's thinking, "I need to get this water as close to a boil as possible before the sun goes down, but I must never boil the water."

In this analogy, the temperature of the water represents battery voltage; the flow of gas represents charging current; boiling represents overcharge; and the energy chef manipulating the valve is like the charge controller.

Some controllers regulate the flow of energy to the battery by switching the current fully on or fully off. This is called on/off control. Others reduce the current gradually, called pulse width modulation (PWM). Both methods work well when the voltage set points are properly selected for your type of battery.

The Energy Chef



A PWM controller holds the voltage more constant. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then it will drop the voltage lower to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress.

The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated pattern of use, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. Some controllers have adjustable set points, while others do not.

Control Set Points vs Temperature

The ideal set points for charge control vary with battery temperature. Some controllers have a feature called temperature compensation. When the controller senses a low battery temperature, it will raise the set points. Otherwise when the battery is cold, it reduces the charge too soon. If your batteries are exposed to temperature swings greater than about 30°F (17°C), compensation is essential.

Some controllers have a temperature sensor built in. This type of controller must be mounted in a place where the temperature is close to that of the batteries. Better controllers have a remote temperature sensor on a small cable. The probe should be attached directly to a battery in order to report its temperature to the controller.

An alternative to automatic temperature compensation is to manually adjust the set points (if possible) according to the seasons. It may be sufficient to do this only twice a year, in spring and fall.

Control Set Points vs Battery Type

The ideal set points for charge controlling depend on the battery design. The vast majority of RE systems use deep cycle lead-acid batteries of either the flooded type or the sealed type. Flooded batteries are filled with liquid. These are the standard, economical deep cycle batteries.

Sealed batteries use saturated pads between the plates. They are also called "valve-regulated," "absorbed glass mat," or simply "maintenance-free." They need to be regulated to a slightly lower voltage than flooded batteries or they will dry out and be ruined. Some controllers have a means to select the type of battery. Never use a controller that is not intended for your type of battery.

Low Voltage Disconnect

The deep cycle batteries used in renewable energy systems are designed to be discharged a maximum of 80 percent (20% state of charge). If they are discharged 100 percent, they are immediately damaged. Imagine a pot of water boiling on your kitchen stove. The moment it runs dry, the pot overheats. If you wait until the steaming stops, it is already too late!

Typical Set Points for 12 V L-A Batteries at 77°F (25°C)

Set Point	*Voltage*
High limit (flooded battery)	14.4 V
High limit (sealed battery)	14.0 V
Resume full charge	13.0 V
Low voltage disconnect	10.8 V
Reconnect	12.5 V
Typical temperature compensation per 1°C deviation from 25°C	-0.03 V

These are typical set points, presented here only for example.

Similarly, if you wait until your lights look dim, some battery damage will have already occurred. Every time this happens, both the capacity and the life of the battery will be reduced by a small amount. If the battery sits in this overdischarged state for days or weeks at a time, it can be ruined quickly.

The only way to prevent overdischarge when all else fails is to disconnect loads (appliances, lights, etc.), and then reconnect them only when the voltage has recovered due to some substantial charging. When overdischarge is approaching, a 12 volt battery will drop below 11 volts (a 24 V battery will drop below 22 V).

A low voltage disconnect (LVD) circuit will disconnect loads at that set point. It will reconnect the loads only when the battery voltage has substantially recovered due to the accumulation of some charge. A typical LVD reset point is 13 volts (26 V on a 24 V system).

All modern inverters have LVD built in, even cheap pocket-sized ones. The inverter will turn off to protect itself, your loads, and your battery. Normally, an inverter is connected directly to the batteries, not through the charge controller, because its current draw can be very high, and because it does not require external LVD.

If you have any DC loads, you should have an LVD. Some charge controllers have one built in. You can also obtain a separate LVD device. Some LVD systems have a "mercy switch" to let you draw a minimal amount of energy, at least long enough to find the candles and matches! DC refrigerators have LVD built in.

If you purchase a charge controller with built-in LVD, make sure that it has enough capacity to handle your DC loads. For example, let's say you need a charge controller to handle less than 10 amps of charge current, but you have a DC water pressurizing pump that draws 20 amps (for short periods) plus a 6 amp DC lighting load. A charge controller with a 30 amp LVD would be appropriate. Don't buy a 10 amp charge controller that has only a 10 or 15 amp load capacity!

Overload Protection

A circuit is overloaded when the current flowing in it is higher than it can safely handle. This can cause overheating and can even be a fire hazard. Overload can be caused by a fault (short circuit) in the wiring, or by a faulty appliance (like a frozen water pump). Some charge controllers have overload protection built in, usually with a push-button reset.

Maximum Power Point Tracking

A new feature is showing up in charge controllers. It's called maximum power point tracking (MPPT). It extracts additional power from your PV array under certain conditions.

The function of MPPT is analogous to the function of a transmission in a car. When the transmission is in the wrong gear, the wheels do not receive maximum power. That's because the engine is running either slower or faster than its ideal speed range. The purpose of the transmission is to couple the engine to the wheels in a way that lets the engine run in a favorable speed range in spite of varying acceleration and terrain.

Let's compare a PV module to a car engine, with voltage analogous to engine speed. At the ideal voltage, the PV can deliver maximum power. This is the maximum power point, also called peak power voltage (Vpp). Vpp varies with sunlight intensity and with solar cell temperature. The voltage of the battery is analogous to the speed of the car's wheels. It varies with battery state of charge, and with the loads on the system (any appliances and lights that may be on). For a 12 V system, it ranges from about 11 to 14.5 volts.

In order to charge a battery (increase its voltage), the PV module must apply a voltage that is higher than that of the battery. If the PV module's Vpp is just slightly below the battery voltage, then the current drops nearly to zero (like an engine turning slower than the wheels). To play it safe, typical PV modules are designed with a Vpp of around 17 volts when measured at a cell temperature of 77°F (25°C) on a cool day. They do that because it will drop to around 15 volts on a very hot day. However, on a very cold day, it can rise to 18 volts!

What happens when the Vpp is much higher than the voltage of the battery? The module voltage is dragged down to a lower-than-ideal voltage. Traditional charge controllers transfer the PV current directly to the battery without giving you the benefit of this added potential.

Now let's make one more analogy. The car's transmission varies the ratio between speed and torque. At low gear, the speed of the wheels is reduced and the torque is increased. Likewise, MPPT varies the ratio between the voltage and current delivered to the battery in order to deliver maximum power. If there is excess voltage available from the PV array, it is converted to additional charging current for the battery. It's like an automatic transmission. As the Vpp of the PV array varies with temperature and other conditions, it "tracks" this variance and adjusts the ratio accordingly. That's why it's called a maximum power point tracker.

What advantage does MPPT give in the real world? That depends on your array, climate, and seasonal load pattern. It gives you an effective current boost only when the Vpp is more than about 1 volt higher than the battery voltage. In hot weather, this may not be the case unless the batteries are at a low state of charge (SOC). In cold weather however, the Vpp can rise as high as 18 volts. If your energy use is greatest in the winter (typical in most homes) and you have cold winter weather, then you can gain a substantial boost in energy when you need it the most!

Here is an example of MPPT action on a cold winter day:

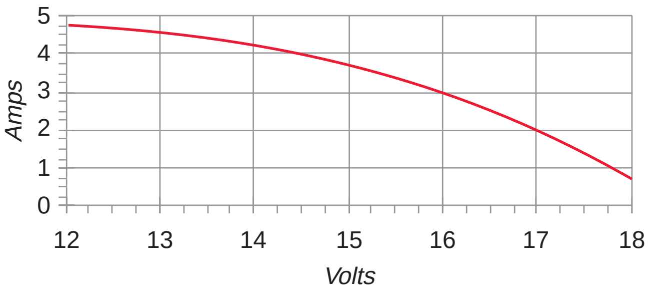
The outside temperature is 20°F (-6.6°C). The wind is blowing a bit, so the PV cell temperature rises to only around 30°F (-1.1°C). Vpp = 18.0 V. The batteries are a bit low, and loads are high, so battery voltage = 12.0 V.

Ratio of Vpp to battery voltage is 18:12 = 1.5:1

Under these conditions, a perfect MPPT (with no voltage drop in the array circuit) would deliver a 50 percent increase in charge current! In reality, there are losses in the conversion just as there is friction in a car's transmission. Reports from the field indicate that increases of 20 to 30 percent are typically observed.

MPPT controllers are a new technology that is just starting to become available. This sidebar is a simplified introduction to a complex topic. Watch for more information in future issues of *Home Power.*

Typical PV IV Curve



Built-in overload protection can be useful, but most systems require additional protection in the form of fuses or circuit breakers. If you have a circuit with a wire size for which the safe carrying capacity (ampacity) is less than the overload limit of the controller, then you must protect that circuit with a fuse or breaker of a suitably lower amp rating. In any case, follow the manufacturer's requirements and the *National Electrical Code* for any external fuse or circuit breaker requirements.

Displays and Metering

Charge controllers include a variety of possible displays, ranging from a single red light to digital displays of voltage and current. These indicators are important and useful. Imagine driving across the country with no instrument panel in your car! A display system can indicate the flow of power into and out of the system, the approximate state of charge of your battery, and when various limits are reached.

If you want complete and accurate monitoring however, spend about US$200 for a separate digital device that includes an amp-hour meter. It acts like an electronic accountant that keeps track of the energy available in your battery. If you have a separate system monitor, then it is not important to have digital displays in the charge controller itself. Even the cheapest system should include a voltmeter as a bare minimum indicator of system function and status.

Have It All with a Power Center

If you are installing a system to power a modern home, then you will need safety shutoffs and interconnections to handle high current. The electrical hardware can be bulky, expensive, and laborious to install. To make things economical and compact, obtain a ready-built power center. It can include a charge controller with LVD and digital monitoring as options. This makes it easy for an electrician to tie in the major system components, and to meet the safety requirements of the *National Electrical Code* or your local authorities.

Charge Controllers for Wind and Hydro

A charge controller for a wind-electric or hydro-electric charging system must protect the batteries from overcharge, just like a PV controller. However, a load must be kept on the generator at all times to prevent overspeed of the turbine. Instead of disconnecting the generator from the battery (like most PV controllers) it diverts excess energy to a special load that absorbs most of the power from the generator. That load is usually a heating element, which “burns off” excess energy as heat. If you can put the heat to good use, fine!

Is It Working?

How do you know if a controller is malfunctioning? Watch your voltmeter as the batteries reach full charge. Is the voltage reaching (but not exceeding) the appropriate set points for your type of battery? Use your ears and eyes—are the batteries bubbling severely? Is there a lot of moisture accumulation on the battery tops? These are signs of possible overcharge. Are you getting the capacity that you expect from your battery bank? If not, there may be a problem with your controller, and it may be damaging your batteries.

Control Your Charge!

The control of battery charging is so important that most manufacturers of high quality batteries (with warranties of five years or longer) specify the requirements for voltage regulation, low voltage disconnect, and temperature compensation. When these limits are not respected, it is common for batteries to fail after less than one quarter of their normal life expectancy, regardless of their quality or cost.

A good charge controller is not expensive in relation to the total cost of a power system, nor is it very mysterious. I hope this article has given you the background that you need to make a good choice of controls for your power system.

Access:

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Things That Work

Tested by Home Power

EN-R-PAK 200: Portable Power by National Solar Technologies, Inc.

Tested by Joe Schwartz, with help from Dave Wilmeth and Richard Perez

Thinking about putting together a small, portable PV system to take with you on the road this summer? Check out National Solar Technologies' EN-R-PAK 200 before you do.

The standard 115 VAC unit includes a molded plastic carrying case that houses the battery, charge controller, basic metering, and a 200 watt sine wave inverter. A 49 watt PV module with an adjustable mount is included, along with a compact fluorescent lamp. The unit weighs in at 83 pounds (38 kg), plus 32 pounds (15 kg) for the PV and mount. It has a list price of US$1,649.

Intended Use

The EN-R-PAK is designed for temporary, recreational, or emergency use. It's ideal for powering small loads such as lights, communications gear, laptops, TVs, CD players, and small water pumps. The user's manual includes a great section detailing what loads or combinations of loads you can expect to run on the unit for a given length of time.

For example, assuming fairly sunny conditions and continuous rather than weekend use, the unit will power three 15 watt compact fluorescent lights for two hours, a twelve inch (30 cm) energy efficient color TV for two hours, and a 60 watt water pump for one hour for every day of sun. The EN-R-PAK sure won't power your house, and it isn't intended to. But if you need a portable source of high quality AC or DC power, take a closer look.

Product Features

The EN-R-PAK 200 includes a framed, 49 watt ASE single crystalline PV module and aluminum ground mount. The PV charges a user-replaceable, 12 volt, 96 amp-hour sealed gel cell battery. A 20 amp charge controller is built into the EN-R-PAK unit and regulates battery charging. The controller is designed for expansion, and additional PV modules can easily be added to the system.

A second DC input is also provided so that a small wind generator, like an Air 403, can supplement battery charging. A built-in 35 watt AC charger enables the battery to be trickle-charged from the grid or a well-regulated engine generator. This rounds out the EN-R-PAK's charging capabilities.

The unit has two fused 12 volt DC outlets. One is an automotive cigarette-type receptacle. The other is a switched two-wire jack that accepts terminals commonly available from electronics and automotive suppliers. The two outlets have a maximum combined output of 15 amps at 12 VDC. In addition, two switched AC receptacles provide 115 VAC output from a 200 watt sine wave inverter. A metering system with four LEDs indicates battery voltage and whether the battery is being charged or discharged. It also identifies several fault conditions, such as low battery voltage and high temperature.

Installation

Anyone who has hooked up an EN-R-PAK will agree that setup is a snap. The PV module is factory mounted to an adjustable aluminum frame. Simply secure it in the desired location, orient it to true south, and adjust the PV to the desired tilt angle using four wing nuts.

One end of the 33 foot (10 m) DC power cord is pre-wired into the PV module's junction box. The other end

is wired to a polarity-correct plug that connects directly to the EN-R-PAK's DC input. Pop the provided 30 amp fuse into the back of the unit, bring on the sun, and your EN-R-PAK is up and charging.

Because the EN-R-PAK is a portable unit, it's easy to plunk it down on the nearest picnic table and put it to work. But heat is the number one killer of electronics, and that includes charge controllers and inverters. To minimize component heat stress, care should be taken to locate the EN-R-PAK base unit in a shaded location.

Operation On and Off the *Home Power* Grid

Home Power began testing the EN-R-PAK at the 1998 Midwest Renewable Energy Fair (MREF). It powered up Ben's electric hair clippers for a sweltering midwestern summer afternoon of solar buzz cuts. Luckily for the fairgoers, *Home Power's* experimental subsidiary, *A Hair Razing Experience,* wasn't in existence for more than a couple of hours. The impact on the handful of folks courageous enough to sit down in Ben's chair was much more lasting….

Back in Oregon, the EN-R-PAK was installed in a trailer used by Dave, *Home Power's* taskmaster and resident audiophile. He put it to regular use, and it performed well during the nine months it was installed there. It allowed him to unplug from the *Home Power* electric grid entirely.

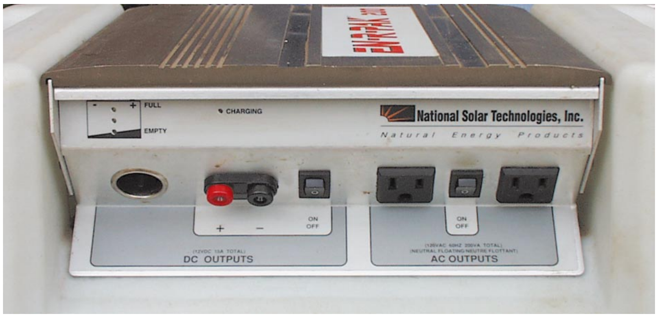
For the remainder of the summer and through the fall, the EN-R-PAK powered all the electric appliances in the trailer. A typical daily load averaged 150 to 200 watt-hours and included a couple of compact fluorescent lights, a coffee grinder, and a stereo pumping out a healthy daily dose of high-torque rock and roll.

The lower sun angle, shorter day length, and a marginal PV location in the trees made for a tough winter season for the EN-R-PAK. In addition, its location in the trailer, which is mostly an unconditioned space, subjected the unit to below freezing temperatures. It's important to point out that in many locations, any single module PV system may have a hard time reliably supporting even a modest load during the winter months.

Fortunately for Dave, the executives at *Home Power & Light* were more than happy to reconnect his utility service. The EN-R-PAK's AC charger and internal transfer switch allowed Dave to power his loads directly from the *Home Power* grid and trickle charge the EN-R-PAK's battery simultaneously.

EN-R-PAK Test Data

Load Watts	*Battery Voltage*	*Vp Output*	*Vrms Output*
18	12.51	161.6	114.8
33	12.39	162.4	114.9
55	12.23	163.6	114.9
90	12.14	172.8	114.8
147	11.84	172.8	115
168	11.69	172.8	115



The EN-R-PAK's control panel.

Test Data

Performance data for the EN-R-PAK was taken using a Fluke 87 digital multimeter and a Brand model 20-1850 digital power meter. The AC operating voltage was consistently within specification at or slightly below 115 VAC. The inverter also held its peak voltage well under load. And when we tried to overload it, the EN-R-PAK's protective circuitry shut down the inverter due to an overcurrent fault condition at 203 watts.

Suggestions

Dave lived with the EN-R-PAK for nine months and had very few gripes about its operation. A small system like the EN-R-PAK benefits greatly from good load management. It's important to use energy efficient appliances like compact fluorescent lights, and always shut off appliances when they're not in use.

According to the manufacturer, the idle draw of the inverter is 3.5 watts. An additional LED on the inverter output would be a good visual reminder to turn off the inverter when it is not in use.

Summer's Here

The EN-R-PAK 200 is a compact, portable, and highly user-friendly source of both DC and sine wave AC power. It's a great unit for light recreational use. So ditch those glaring propane lanterns on your next camping trip and bring along an EN-R-PAK. It's a well-built product that is true to the concept of plug and play.

Access

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Fax: 530-475-0836 • joe.schwartz@homepower.com

Manufacturer: National Solar Technologies, Inc., 1 Elmview Ave., Hamburg, NY 14075 • 800-310-7413 or 716-649-1324 • Fax: 716-649-8655
sales@en-r-pak.com • www.en-r-pak.com

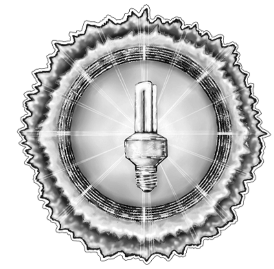
Guerrilla Solar Manifesto

We hold these truths to be self-evident, that all energy is freely and democratically provided by Nature, that utilities both public and private have no monopoly on the production and distribution of energy, that this century's monopolization of energy by utilities threatens the health of our environment and the very life of our planet.

We, the Solar Guerrillas of this planet, therefore resolve to place energy made from sunshine, wind, and falling water on this planet's utility grids with or without permission from utilities or governments. We resolve to share this energy with our neighbors without regard for financial compensation. We further resolve that our renewable energy systems will be safe and will not harm utility workers, our neighbors, or our environment.

Solar Guerrillas of Planet Earth

Home Power's Business



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Must either bust or advertise."
Sir Thomas Lipton — 1870

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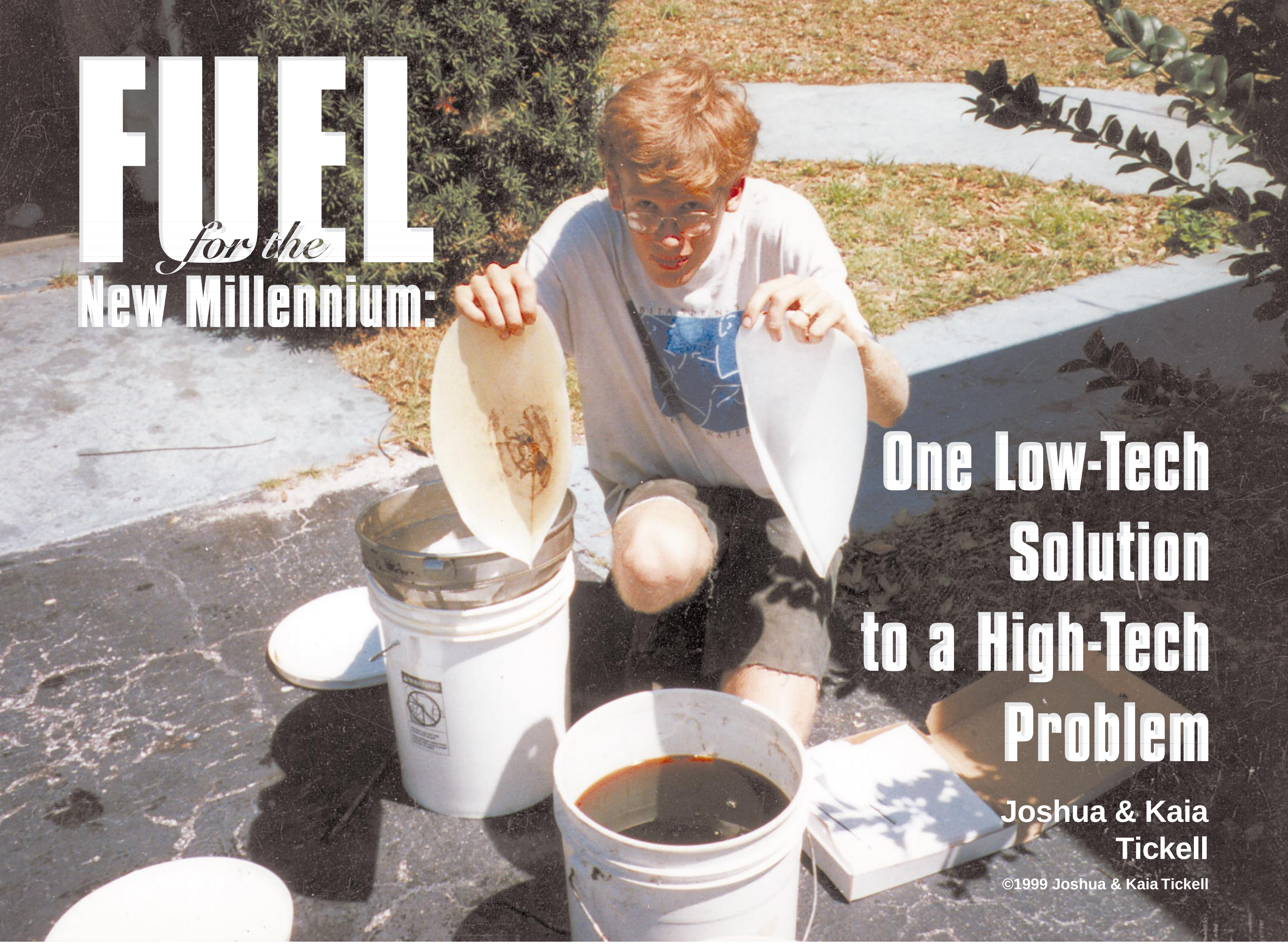
FUEL for the New Millennium:

One Low-Tech Solution to a High-Tech Problem

Joshua & Kaia Tickell



Restaurant fryer filters are available at restaurant supply stores and are excellent for filtering food particles out of used cooking oil.

Making your own fuel from vegetable oil can be easy, cost-effective, and environmentally beneficial. What makes this fuel even more attractive is that you can make it from the waste vegetable oil produced in the United States every year, which amounts to more than three billion gallons. With a bit of know-how and persistence, you can run any diesel engine on vegetable oil.

Only diesel engines can run on vegetable oil-based fuels. This means that any engine that has spark plugs and is made for leaded or unleaded gasoline cannot use vegetable oil fuel. If you want a practical homemade fuel for a gasoline engine, you might consider making ethanol, methane, or wood gas.

Grow Your Fuel

We produce a large quantity of used vegetable oil in the United States, but there is an oilseed crop you can grow no matter where you live. The possibilities include coconut, soybean, canola (rapeseed), sunflower, safflower, corn, palm kernel, peanut, jatropha, and hundreds more. To learn which vegetable oil crop is best suited for your area, contact your state's office of agriculture, the agriculture department of a local university, or talk to local farmers.

One of the crops with the highest yield of oil per acre is canola. From just one acre of canola, you can produce 100 gallons (379 l) of vegetable oil. The most common oilseed crop in the U.S. is soybeans, which produce 50 gallons (189 l) of vegetable oil per acre.

Growing your own oilseed crop has an added bonus. The meal that is separated from the oil is an excellent source of protein. This meal can be used as animal feed or in breads, spreads, and other food products.

Pressing the oil from the seed does not require a large, expensive press. TabbyPressen of Sweden makes a

tabletop press for around US$1,000. Although the press usually comes with a 240V/50 cycle electric motor, you can buy the press with a 120V/60 cycle motor from the U.S. distributor. The press looks like a powerful juicer. To operate it, pour the oilseed into the funnel and wait for the vegetable oil to pour out of the bottom. The meal oozes out of the side of the press.

The Three Ways to Use Vegetable Oil as a Fuel

Diesel engines that are found in cars, trucks, generators, boats, buses, trains, planes, pumping stations, tractors, and agricultural equipment can all run on fuel from vegetable oil. Pure vegetable oil, lard, and used cooking oil work just as well as diesel fuel.

Biodiesel

The most conventional method of running a diesel engine on vegetable oil fuel is to produce a fuel called biodiesel. Biodiesel is made by combining 10 to 20 percent alcohol with 0.35 to 0.75 percent lye and 80 to 90 percent vegetable oil. A very reliable reaction can be made with 80 parts new vegetable oil, 20 parts methanol, and 0.35 parts lye. These ingredients are mixed together for an hour and left to settle for eight hours.

After the chemical reaction is complete and the new products settle out, you have biodiesel fuel and glycerin soap. The fuel is yellow to amber in color and flows like water. The soap is brown in color and has the consistency of gelatin. The soap settles to the bottom, allowing you to pump, siphon, or pour off the biodiesel.

Veggie/Kero Mix

The second method for using vegetable oil in a diesel engine is to simply “cut” the oil with kerosene. This method is best suited for emergencies, heavy duty engines, and warm temperatures. Although it is possible to mix other petroleum products with vegetable oil, kerosene is most suited for the diesel engine.

Depending on ambient temperature, the blend of kerosene to vegetable oil will be anywhere from 10 percent kerosene and 90 percent vegetable oil to 40 percent kerosene and 60 percent vegetable oil. A fairly reliable blend is 20 percent kerosene to 80 percent vegetable oil.

The effectiveness and reliability of the veggie/kero method is increased by starting and cooling down the diesel engine on diesel fuel or biodiesel fuel. This can be accomplished by installing an extra fuel tank and switching to the veggie/kero mix when the engine is warmed up.

Straight Vegetable Oil

The third method for running a diesel engine on vegetable oil is to use straight vegetable oil. As with the other methods, you can use either pure vegetable oil or used cooking oil. To ensure the reliability and longevity of your diesel engine, the engine must be started and cooled down on diesel or biodiesel fuel. This also requires the use of an extra fuel tank and a valve to switch between the tank of diesel or biodiesel fuel and the tank of vegetable oil. Think of it as a startup tank and a running tank.

Our friend, Hugo Brown, pouring grease. A container of used cooking oil can be found behind most restaurants.

The key to running a diesel on straight vegetable oil is to heat the vegetable oil at every stage—in the fuel tank, fuel hose, and fuel filter. The vegetable oil must be heated to at least 70°C (160°F).

Most diesel engines have hoses that carry hot coolant. This coolant can be channeled to heat the vegetable oil hoses, tank, and filter. You can make simple modifications to the coolant hoses. These modifications combined with some extra fuel and oil hoses, an extra fuel tank, and an electrically operated switch will allow you to run your diesel engine on straight vegetable oil.

Fuel Comparison

The chart will show you the differences between the three vegetable oil fuel methods. As you can see, biodiesel is a good substitute or additive fuel for diesel fuel. Veggie/kero mix is decent for use as an emergency fuel. And using straight vegetable oil is good if you have the time and know-how to properly modify

Comparison of Different Vegetable Oil Fuel Methods

Property	*Biodiesel*	*Veggie/Kero Mix*	*Straight Veggie Oil*
Can be used as lubrication additive to diesel fuel	yes	no	no
Requires vehicle modification	no	yes	yes
Reliably cuts emissions in all diesel engines	yes	no	unknown *
Considered an alternative fuel under the United States Energy Policy Act (EPACT)	yes	no	yes **
Simple way to run a vehicle in an emergency	no	yes	no
Stable fuel at room temperature	yes	no	no
Requires added chemicals to produce	yes	yes	no
Requires startup tank of biodiesel or diesel fuel	no	yes	yes
Good startup fuel	yes	no	no
Better lubrication than diesel fuel	yes	yes	yes
Gels in cold weather	yes	yes	yes
Covered by many engine warranties	yes	no	no
Can be made from used cooking oil	yes	yes	yes
Can be made from pure vegetable oil	yes	yes	yes
Safe to store and handle, biodegradable, won't spontaneously ignite, and non-toxic	yes	no	yes
Works in all diesel engines	yes	yes	yes
Can be reliably mixed in any proportion with diesel fuel without vehicle modification	yes	no	no
Approved for use by EPACT in a 20% mix with 80% diesel fuel ***	yes	no	no
Engine life, power, torque, fuel mileage, and overall performance are relatively unaffected	yes	yes	yes
Can clog fuel injectors if used improperly	no	yes	yes
Requires heating for operation at any temperature	no	no	yes
Tested and documented by U.S. universities	yes	no	yes
Possible substitute for home heating oil in furnaces	yes	no	no
Can be used in Petromax brand and similar lanterns and stoves	yes	no	yes

* No recent U.S. University studies have been published on this.

** Under EPACT regulations, any biologically-derived fuel is considered an alternative fuel.

*** EPACT legislation states that a fleet must use a minimum of 450 gallons (1703 l) of biodiesel per year.

your engine's heating and fuel tank systems. Diesel engines are used in many different situations. For each situation, there is a way to make fuel from vegetable oil.

How to Make Biodiesel

This section outlines the process for making biodiesel fuel from new vegetable oil or used cooking oil. This fuel can be made in a blender or in a larger, homebuilt mixer. The materials you'll need are vegetable oil, methanol, and lye.

If you are using new vegetable oil, always use 3.5 grams of lye per liter of oil. Since each batch of *used* cooking oil is different, the amount of lye in each batch of biodiesel will be different. To ensure that you are using the correct amount of lye, make a small test batch of biodiesel in a blender before attempting a reaction in a large mixing tank. For the test batch, use 100 milliliters of vegetable oil and 20 milliliters of methanol. Then you must determine how much lye to use.

If you are using used vegetable oil, use 0.45 grams of lye for the first test batch. If this batch makes biodiesel and glycerin, use the same proportions for the large batch reaction. If the test batch does not form two distinct layers, increase the amount of lye to 0.55 grams and make another test batch. If this batch is unsuccessful, make another batch and increase the amount of lye to 0.65 grams. If that batch is unsuccessful, make another batch with 0.75 grams of lye. Make sure you can make biodiesel on a small scale before attempting a large reaction.

Once you have made a successful small test batch of biodiesel, multiply the number of grams of lye you used by ten to see how much lye you will need for each liter of oil in the large reaction. For example, if you used 0.55 grams of lye in the test batch, you will need to use 5.5 grams of lye per liter of used cooking oil for a large reaction.

Here is the basic procedure for making biodiesel fuel. Read the safety information at the end of this article before you begin.

1. Purchase or collect new or used vegetable oil.
2. If the oil is used cooking oil, use a restaurant fryer filter to remove burned food bits, etc.
3. Purchase some methanol alcohol from a local racetrack or chemical supply store. Ethanol alcohol can also be used, but the process is different.
4. Purchase some granulated lye (Red Devil is one brand) or caustic soda sold as a drain cleaner from the hardware or grocery store. It must be pure sodium hydroxide (NaOH).
5. Measure the amount of vegetable oil you want to use in liters. We will call this number V. Pour the vegetable oil into the mixing container.
6. When the temperature is below 70°F (21°C), or when the vegetable oil is solid or lumpy, it will be

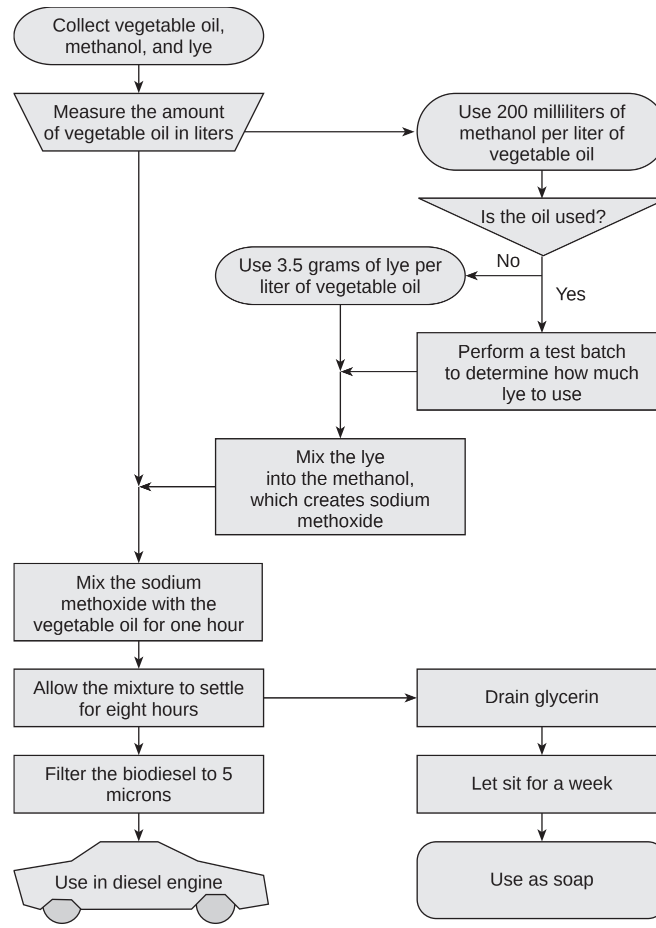
necessary to heat the reactants before, during, and possibly after the mixing. The ideal temperature to attain is 120°F (49°C). A fish tank heater will heat 10 to 30 gallons (40–120 l) of reactants. For larger batches of biodiesel, a water heater element can be mounted in a steel biodiesel mixing tank. Make sure that you follow the manufacturer's directions and safety precautions when adding any electrical device to the system. Be careful when heating vegetable oil in a plastic container. Polyethylene cannot withstand temperatures above 140°F (60°C).

7. Multiply V x 0.2. The result will be the amount of methanol you will need in liters. We will call this number M.
8. To determine how much lye you will need to use for new vegetable oil, multiply V times 3.5 grams. For used vegetable oil, use the number of grams of lye you got in the small test batch. For example, if you used 0.55 grams of lye in the test batch, you will multiply V times 5.5 grams of lye. Call this number L.
9. Carefully pour L grams of lye into M liters of methanol. Stir until the lye is dissolved in the methanol. Be careful, this creates a toxic substance called sodium methoxide.
10. Pour the sodium methoxide into the vegetable oil right away. Stir vigorously for one hour.
11. Let the mixture settle for eight hours.
12. Pump the biodiesel from the top, or siphon it off with a hand siphon. Or if you are lucky enough to have a container with a spigot, open the spigot and drain the bottom layer of glycerin. The glycerin will be much thicker and darker than the top layer of biodiesel.
13. Allow the glycerin to sit in the sun for a week. After that, the trace methanol will be evaporated. You have made a nice glycerin soap. You can scent it with the fragrance of your choice, add other soap agents as desired, or just use it as it is. This soap is especially good for cleaning grease off your hands and cleaning greasy equipment!
14. Make sure your biodiesel goes through a 5 micron filter before entering your diesel engine.

A Simple Biodiesel Processor

The simplest way to make a biodiesel processor is to use a 55 gallon (208 l) steel drum and some sort of mixer. The mixer can be a circulating pump, such as a sump pump, or it can be an electric mixer for chemicals, specially made for drum stirring.

Making Biodiesel Flow Chart



A pump or stirrer will cost about US$200 if you buy it new, but you can build your own instead. With a bit of ingenuity, you can build a biodiesel processor that is inexpensive and effective. Tim Garrits of Kelseyville, California built such a processor from mostly recycled parts for under US$50. A simple biodiesel processor can be built from the following parts:

- A 55 gallon (208 l) metal drum.
- A 1/2 hp electric motor.
- Two pulleys that give about 250 to 400 rpm at the mixer blade.
- A belt that goes around both pulleys.
- A rolled 2 inch (5 cm) rod for the mixer shaft.
- A propeller made from two shelf brackets, welded to either side of the rolled 2 inch rod. The shelf brackets look like two opposed "L"s and form a propeller about 14 inches (36 cm) in diameter. Basically any propeller-shaped metal would do, if it is made from about 12 or 14 gauge steel.

- A 3/4 inch (19 mm) brass ball valve for draining the glycerin.
- A hinge and piece of wood acting as a belt tensioner.
- A 2,000 watt electric water heater element.
- A water heater thermostat.
- Wood, screws, bolts, and other assorted mounting hardware.

A Note of Caution

You are dealing with dangerous chemicals when you make biodiesel. Both methanol and lye are strong bases. They can deaden nerve endings and cause permanent damage. For this reason, chemical resistant gloves, aprons, and eye wear should be worn when dealing with methanol and lye. Shoes, long sleeve shirts, and long pants are a must.

Keep both methanol and lye in clearly marked containers. We recommend putting a skull and crossbones on them and writing something to the tune of “Danger! Toxic! Do Not Eat!” in addition to the contents.

Sodium methoxide, the chemical combination of lye and methanol, is even more toxic than the separate components. Keep this stuff away from any exposed skin. Do not let children play in or around biodiesel equipment. Remember, although you are creating two chemically benign substances when you make biodiesel, you are using dangerous chemicals in the process.

Always keep safety in mind when preparing a biodiesel reaction. Have a faucet or hose nearby. Keep some vinegar handy to neutralize any methanol or lye that may spill. If you take the time to prepare and follow safety guidelines, your biodiesel reaction will go smoothly and you should have no problems.

Fuel Tax & Engine Specifications

If you live in the U.S., you are responsible for paying the IRS for any on-road fuel that is not taxed at the pump. If you live outside the U.S., it would be wise to check with local authorities as to taxation.

You are responsible for any damage that may result to your engine if you use a fuel that does not meet your engine manufacturer’s specifications.

Go For It!

Disclaimers aside, biodiesel is used all over the world. Island people are making biodiesel from coconut oil, some countries are experimenting with biodiesel from hemp seed oil, and many others are using canola oil. Millions of miles of road tests have been done with this fuel. Tests have shown less wear on the internal components of engines using biodiesel.

Biodiesel is a reliable, exciting fuel that you can make. If you are worried about your diesel engine, you can install an extra fuel filter system from Racor or a similar aftermarket parts manufacturer. After traveling over 25,000 miles (40,000 km) on biodiesel made from used cooking oil, we continue to choose and recommend biodiesel over toxic, carcinogenic petroleum diesel fuel.

Complete instructions, diagrams, photos, and parts lists for the three methods of running a diesel engine on vegetable oil and building a biodiesel processor are included in the new, second edition of *From the Fryer to the Fuel Tank.*

Access

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New Second Edition! *From the Fryer to the Fuel Tank: The Complete Guide to Using Vegetable Oil as an Alternative Fuel* by Joshua and Kaia Tickell, US$29.95 postpaid (outside USA add US$5) from BookMasters, PO Box 388, Ashland, OH 44805 • 800-266-5564 or 419-281-1802 • Fax: 419-281-6883
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The Acid Test: EV Batteries

Shari Prange

The most frequently asked electric vehicle question is, "What's the best battery?" The question is short and simple, but the answer is long and complex. I'm going to try to simplify it for you.

The best battery for your car depends on your priorities. Do you need lots of miles or lots of speed and acceleration? Is the limiting factor your available space for batteries, or is it your budget? We'll look at several characteristics of the most commonly used batteries and compare them. You'll see that many of these characteristics are inextricably intertwined.

Types of Batteries

For now, we'll limit ourselves to batteries using lead-acid technology. We can narrow the field further by eliminating some types of batteries that simply aren't appropriate for electric vehicles. For example, the conventional starting battery in a gas car is designed for a high current output and a very brief, shallow discharge. On the other hand, an RV battery or marine trolling battery is designed to tolerate repeated deep discharges, but at a fairly low current draw. Neither of these will hold up for long in the high current draw, deep discharge application of an electric car.

The Conventional Conversion Standard

As our baseline, we'll use the flooded 6 volt golf car battery. "Flooded" batteries have a large amount of liquid electrolyte in them. They have access caps so you can periodically check and top off the fluid level. The golf car battery is a true traction battery, designed to move a vehicle and hold up under both high current draw and deep discharge. This has been the workhorse of EV conversions for decades, the most common choice by a wide margin.

There are only a handful of manufacturers building these batteries, and two of them dominate the market: U.S. Battery and Trojan Battery. Most other brands that you see are built by one of these and sold under different labels. For example, Interstate golf car batteries are manufactured by U.S. Battery.

There are a few different models of golf car batteries. They vary slightly in size and weight, with the larger, heavier ones having more capacity. The most commonly used models are the mid-range ones, generally rated for 230 to 235 amp-hours at the 20 hour rate. We'll talk more about rates later.

Other Lead-Acid Batteries

There are only a few other types of lead-acid batteries that are actually in production and appropriate for EV conversions. In addition to the flooded 6 volt models, there are also flooded 8 volt and flooded 12 volt traction batteries.

Another type is the "maintenance free" battery. These are also variously called starved electrolyte, valve regulated, or absorbed glass mat (AGM) batteries. Unlike flooded batteries, they have relatively little liquid electrolyte, which is held against the plates in mats. They cannot be opened for service. For electric cars, these include 12 volt batteries from Optima Battery and Hawker Energy Products.

Although these batteries are commonly referred to as "sealed," Bill O'Brien, EV specialist for Hawker, says that they are not truly sealed. It's true that there is no cap to open for adding water, and if you turn them upside down, nothing will

run out. However, it is necessary for the batteries to be able to vent if pressure builds up inside from overheating, which can occur if the battery is overcharged. A valve allows this to happen in a controlled manner. We can continue to call them “sealed” batteries for convenience, as long as we understand the reality.

Range

Many people consider range to be the most important feature of a battery. To determine how far the EV can go before it has to be recharged, we have to acknowledge that range is affected by many things. Some of them have nothing to do with the batteries directly, such as terrain, traffic flow, vehicle weight, and driving style.

Batteries are used in packs, not as individual units. If you are comparing single batteries, you can compare amp-hour ratings, but in packs, you have to consider other factors. When wired in series, with the negative post of one battery connected to the positive post of the next, the voltage increases with each battery added, while the amp-hour capacity remains the same.

Even though adding more batteries does not change the amp-hour capacity of the pack, it does extend range by spreading the load over more batteries. A car with a higher voltage system will not draw as much current, so it will have a higher range than a car with a lower voltage system with the same type of batteries. The batteries are not being discharged as deeply in the high voltage system.

Similarly, look at two cars with the same system voltage—one with a single pack of batteries, and the other with two packs wired in parallel. The twin-pack car will have the higher range because it has split the current demand between the two packs. The range will actually be more than double compared to the range of a single string, because the relationship between range and current capacity is curved instead of linear.

In parallel wiring, connections are made negative to negative and positive to positive. Unlike series wiring, this increases the amp-hour capacity of the system rather than increasing the pack voltage. You can have two packs of batteries, with batteries wired together in series within each pack, and the two packs wired together in parallel. Or you can have pairs of batteries wired together in parallel. These pairs are then treated as single battery units, and the pairs are wired in series into one big pack.

With these things in mind, we can look at the differences between individual battery models. We can think in terms of how many batteries of one type it would take to equal the range of another type.

Measuring Capacity

Range capacity is measured in different ways. The most common ratings are the 20 hour rate and the 75 amp rate. First we’ll talk about the 20 hour rate. This refers to the level of constant current draw that a battery can sustain for twenty hours. The rating equals hours times current draw. For example, a 220 amp-hour battery can sustain a draw of 11 amps for 20 hours (11 x 20 = 220).

Even traction batteries, which are designed to withstand heavy loads, will give their best performance if they are discharged slowly at a low current draw. The battery’s capacity, when measured at the 20 hour rate, is expressed in amp-hours (AH). The golf car battery that is most commonly used in EVs is a 230 AH or 235 AH model.

However, the 20 hour rate doesn’t represent the way the batteries are used in electric cars. A one or two hour rate would be more appropriate, but these numbers are not always available, so it can be difficult to compare between manufacturers. You can’t extrapolate this information from the 20 hour rate, because it is not a simple linear relationship. In fact, almost nothing about batteries is a simple linear function.

What is often available from battery manufacturers is the 75 amp rate. This is expressed in minutes. It represents how many minutes the battery can provide a steady 75 amp current. The 230 AH golf car batteries mentioned earlier are rated for 132 minutes at the 75 amp rate. This rating system still isn’t really well matched to an EV conversion, since many of these cars will draw twice that much current or more just to maintain a cruising speed, but it’s much closer than the 20 hour rate.

Making Comparisons

If you can get ratings for different voltage batteries on the same scale, you can get an approximate idea of the range difference between them by comparing watt-hours (WH). This is volts multiplied by amp-hours. For example, a 6 volt 230 AH battery has 1,380 WH of capacity. By comparison, an 8 volt 165 AH battery has 1,320 WH of capacity.

Even if you have the same rating for two different batteries, you can’t be sure you’re comparing apples to apples. Under the best manufacturing and testing conditions, there is still considerable variation among batteries. Do the published ratings represent the capacity of the average battery in that model, or the best ones?

According to Nawaz Qureshi, battery engineer for U.S. Battery, it is also important how a battery is tested. A battery that yields a 100 AH rating at ambient temperatures will yield

Battery Specifications

Manufacturer	*Model*	*Volts*	*Length*	*Width*	*Height*	*Weight*	*20 Hr Rating*
U.S. Battery	US-2200	6	10.25"	7.125"	11.125"	63 lbs	220 AH
U.S. Battery	US-125	6	10.25"	7.125"	11.125"	67 lbs	230 AH
U.S. Battery	US-145	6	10.25"	7.125"	11.875"	70 lbs	245 AH
Trojan Battery	T-105	6	10.375"	7.125"	11.875"	62 lbs	225 AH
Trojan Battery	T-125	6	10.375"	7.125"	11.188"	66 lbs	235 AH
Trojan Battery	T-145	6	10.375"	7.125"	11.500"	72 lbs	244 AH
U.S. Battery	US-8VGC	8	10.25"	7.125"	11.125"	64.5 lbs	165 AH
Trojan Battery	T-875	8	10.375"	7.125"	11.188"	63 lbs	150 AH
Trojan Battery	T-890	8	10.375"	7.125"	11.188"	69 lbs	165 AH
U.S. Battery	EV-145	12	13.625"	6.75"	12.25"	87 lbs	145 AH
Optima Battery	Yellow Top	12	10"	6.8"	7.8"	42.9 lbs	65 AH
Optima Battery	31	12	13"	6.8"	9.5"	72 lbs	90 AH
Hawker Energy	Genesis G42	12	7.775"	6.525"	6.715"	32.9 lbs	47 AH
Hawker Energy	Genesis G70	12	13.020"	6.620"	6.930"	53.5 lbs	74 AH

115 AH if heated. Another battery from a different manufacturer that provides 115 AH at ambient temperatures will give close to 130 AH if heated. Both may be officially rated at 115 AH. However, you may not be able to find out the temperature at which the rating was done.

So how do you tell the difference? One clue is weight. If two batteries have the same rating but one is a couple of pounds heavier, it has more active material in it, which means it has more capacity.

You can get a rough idea of expected range for your vehicle by multiplying its actual gas mileage by the weight of your battery pack, then dividing by 420 for carbureted cars, or 450 for fuel-injected cars. This is a handy equation, since the gas mileage number will take into account terrain, traffic, chassis weight, and driving style. I don't know why it works, but this equation is commonly passed around among EV hobbyists. Applying it to various conversions of known range has shown that it does give a pretty accurate rough approximation. With EV range, it's hard to get more precise than that.

Size & Weight

This leads to the next two battery characteristics—size and weight. As I mentioned at the beginning, they are interrelated with range. If you need a long-range car, you want as much battery capacity (which means *weight)* as your chassis can safely handle.

But if your range needs are modest and your chosen vehicle has limited space or strength, minimizing the battery's size and weight may be more important to you than its capacity.

The top speed of the car will be determined by the motor's power curves, the gearing of the transmission, and the voltage of the battery pack. For the most commonly chosen cars and components, this means you need at least a 96 volt system for low freeway speeds. Higher voltage will give you higher speed. Most street conversions stop at 144 volts, because beyond that you get into a different category of components and greater expense.

Obviously, if you use 8 volt or 12 volt batteries, you will need fewer of them to reach your desired pack voltage. A 12 volt battery will allow you to reach the same top speed with a physically smaller and lighter battery pack. The tradeoff is range.

The 6 volt golf car batteries are all close to the same dimensions, as you can see from the accompanying chart. The 8 volt flooded batteries have the same dimensions as the 6 volt, but they have four cells crammed into the battery instead of three. In addition, U.S. Battery has a flooded 12 volt battery called the EV 145, which is a true traction battery.

Among the sealed batteries, the Optima Yellow Top and the Hawker Genesis are the most popular models. Optima is also just coming out with a model #31, which Optima EV sales account manager Randy Hively says won't be officially released until late 1999, although some beta test units are already circulating. We'll look at situations where the Optimas really shine next time.

Sealed batteries are somewhat more compact than flooded versions. The Optima Yellow Top uses circular cells, and resembles a beverage six-pack in size and shape.

Crunch the Numbers

Now you can play with these batteries on paper. Substitute one model for another, and see what happens. For example, start with a basic pack of sixteen 6 volt flooded golf car batteries of the mid-range model. This gives you a 96 volt pack weighing 1,056 to 1,072 pounds (479–486 kg) with a 20 hour rating of 230 to 235 AH.

If you hold the pack voltage constant, you could switch to 8 volt batteries, and you would only need to use twelve of them. Your 96 volt pack would take up only 75 percent as much space, weigh 756 to 828 pounds (343–376 kg) and have a 20 hour rating of 150 to 165 AH. This would make sense if you are short of space, or if your chassis can't support the weight of the 6 volt pack, but your range needs are small.

You could go one step further and use the flooded 12 volt batteries, in which case you would only need eight of them. You would have much less range than with the pack of 6 volt or even 8 volt batteries, but you would save even more weight and space, which may be critical for your EV.

Taking a different approach, you could use the same number of 8 volt batteries as there were in the 6 volt pack, which would raise total voltage to 128 volts. Craig Quentin, Trojan battery engineer, notes that this would give you close to the same range as the 96 volt pack of 6 volt batteries, with a higher top speed. The batteries would take up the same amount of space, weigh 1,008 to 1,104 pounds (457–501 kg), and have a 20 hour rating of 150 to 165 AH.

The lower amp-hour rating would be offset by approximately the same weight of active material and a higher voltage system, which means a lighter current draw. Since the packs are different voltages, you need to compare watt-hours. The 96 volt pack of 6 volt batteries will have 22 to 22.5 KWH, while the 128 volt pack of 8 volt batteries will have 19.2 to 21.1 KWH.

Another option would be to put two strings of sealed Optima 12 volt Yellow Top batteries in the same space as a single string of 6 volt golf car batteries. You would still have a 96 volt system with a weight of only 720 pounds (327 kg). The twin strings would essentially double your usable capacity to 130 AH, or 12.5 KWH. You would need three parallel 96 volt strings of Optimas to approach the range of a single string of 6 volt batteries. However, if you have very limited space for batteries, and don't need much range, this setup would give you very good performance.

What's Best For You?

To decide which setup is best for you, first you have to establish your parameters. You might say, "With the components and gearing of my car, I know I need at least 96 volts for an acceptable top speed. My chassis can handle up to 1,100 pounds (499 kg) of batteries. I realistically need a reliable 40 mile (65 km) range."

Then start playing with the numbers for different types of batteries. Which ones will give you the pack voltage you want, will physically fit in the car, and are within your weight limits? Take the weight of this battery pack and plug it into the earlier formula along with your gas mileage, and see if it will give you the range you want.

Capacity, size, and weight are only a few of the critical characteristics of batteries, but they are at the top of the list for many people. Next time we'll talk about some other issues, including cost, cycle life, acceleration, charging, and maintenance.

Access

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Wŏrd Pow´ẽr

Renewable Energy Terms

Watt-hour—unit of energy

Ian Woofenden

Once you know what a gallon is, you should have no trouble seeing that a “gallon per second” is a *rate* of liquid flow. The phrase itself helps us understand. With electricity, the terms tend to confuse us.

At first glance, the term “watt-hour” might sound like a rate. It has a time element, reminding us of “per hour.” And a watt, like a gallon, sounds like a quantity of “stuff.” But in fact, a watt is a rate, and a watt-hour is a quantity. We can compare a watt (technically a joule per second) to the rate water is filling your bucket (a certain number of gallons per second), and watt-hours to the number of gallons in your bucket.

This distinction between watt and watt-hour is crucial! They are not at all the same thing, though they are often mixed up. The terms themselves are confusing, and frequent misuse dulls the distinction for us.

What if you ask your spouse to bring home three gallons per second from the dairy section of the local grocery store? You will wish that you’d specified the time period you had in mind when you get more milk than you expected.

You’ll have a similar confusion if you ask your renewable energy (RE) dealer to design a system that will give you 14,000 watts. He or she will want to know if you need 14,000 watts continuously (an enormous system), or if you are really misusing the terms and mean 14,000 watt-hours per day (a merely huge system). You might also mean that you need 14,000 watts peak, to handle the brief surge when you start all your large power tools and your irrigation pump at once.

If you’re looking for the universal measure for an RE system—watt-hour is it. A watt-hour defines the amount of energy used when we leave a one watt load on for one hour. Just multiply watts times hours and you’ll have watt-hours. Voltage is already factored in, so once you get to watt-hours, you’re using a measure that allows you to compare loads, generating sources, and batteries—regardless of system voltage. When you do your load analysis, convert everything to watt-hours and the process will be much easier.

Folks on the grid buy electrical energy by the kilowatt-hour, which is one thousand watt-hours. When people say that they paid for 50 kilowatts last month, it’s obvious that they don’t understand the terms. It’s like saying you’re going to buy three gallons per second at the dairy—it tells you only the rate, not the total amount.

A closely related terminology confusion is between “power” and “energy.” Electrical energy is measured in watt-hours. Electrical power is the rate of energy flow, and it’s measured in watts. In common speech, we use “power” and “energy” very loosely, and often not in their technically accurate sense. This doesn’t actually bother me too much, since most of our lives are not spent speaking technically. It also seems hopeless to expect the whole population to use these terms in their technical sense. Even the power—Oops! Do I mean energy?—companies can’t seem to keep them straight.

But when it comes to watts and watt-hours, we will only confuse others—and ourselves—by not using the terms correctly. A watt-hour is a measure of energy—it’s a quantity of “stuff.” A watt is the rate at which energy is generated or used.

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Mike Brown

“What’s involved in designing and building a motor adaptor?”

I was talking to a guy at a show about converting a car, and we were listing the parts he needed to buy. When we got to the motor-to-transmission adaptor, he said, “I won’t need an adaptor, I have a friend with a machine shop who said he would help me build one. How hard can it be to build an adaptor?”

Before we answer the question, we need to define “adaptor.” An adaptor is a group of parts that replaces the internal combustion (IC) engine’s crankshaft, to which the flywheel was originally bolted. The adaptor provides a way to attach the electric motor to the transmission. It maintains the alignment between the motor driveshaft and the transmission mainshaft, as well as the flywheel location.

The parts of an adaptor include the transmission profile plate, motor ring, hub, and bushing. The transmission plate bolts to the transmission bellhousing on one side, and to the motor ring on the other side. The ring, in turn, bolts to the motor. These two pieces physically join the electric motor to the transmission.

Both the plate and ring have large holes in their centers. Inside of this open space, the hub and bushing fit together and join the clutch flywheel to the motor shaft. This is what actually transmits the power to turn the car’s wheels. Now let’s look at the individual parts of an adaptor and see how they work together to do the job.

Transmission Profile Plate

I like to say that the transmission profile plate fools the car’s transmission into thinking it is connected to an IC engine instead of an electric motor. But this is only part of its job. The outer perimeter of the plate is cut to follow the shape of the transmission bellhousing as much as necessary, and provides holes that match the mounting holes in the transmission. But its most important job is to accurately locate the motor so the motor shaft is in perfect alignment with the transmission mainshaft.

In the mating surface of the transmission bellhousing (the surface that rests against the rear of the engine block), there are two holes that are larger than the rest of the mounting holes. These holes match two similar holes in the engine block. Inserted in these holes are two hollow tube sleeves called “locating dowels.” These dowels accurately lock the transmission to the engine with the centerlines of the transmission mainshaft and engine crankshaft in perfect alignment.

To duplicate these dowel locations on the profile plate, we first have to determine the mainshaft center. Since a majority of transmission mainshafts are supported at the clutch end by the pilot bearing in an IC engine car, there is both up-and-down and side-to-side play at that end of the mainshaft.

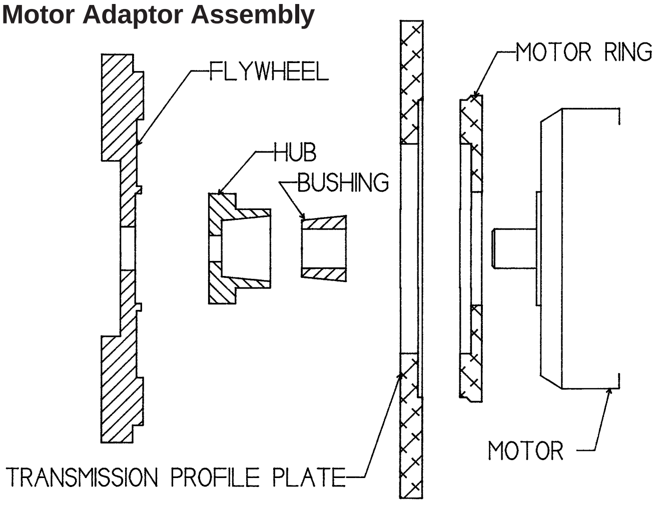
To eliminate this play and precisely lock the mainshaft, I use a specially designed and built fixture to hold the mainshaft at the exact center point, determined with a dial indicator. Over the years, I have built up quite a collection of special tools I had to design just to take the measurements from various vehicles. I am still adding to this collection as I work on new transmissions with different problems to solve. For example, some transmissions have a mainshaft that is recessed in the bellhousing. In order to get true center measurements, I have to build a precise extension to bring the mainshaft location out to the edge of the bellhousing.

Once the mainshaft center is locked in place, I measure the distance between each of the dowels and the mainshaft, between the two dowels themselves, and between the mainshaft and a straight edge across the dowels. I then use trigonometry to check my measurements. All of these measurements are done to three decimal places of accuracy.

The measurements are then transferred to a stencil board pattern that outlines the shape of the bellhousing and locates the less critical holes for the bolts that hold the adaptor plate to the transmission.

The machinist who makes the adaptors for me uses this pattern to cut the aluminum profile plate to shape, and to locate the mainshaft center. When the plate is clamped to the vertical milling machine, he lines up the machine’s spindle with the mainshaft center mark, and moves the mill’s calibrated table to locate the dowel holes, using the

Motor Adaptor Assembly



dimensions taken from my earlier measurements. Then the mounting holes for the bolts that hold the plate to the motor ring are drilled, and the hole for the hub is cut. All of these are located precisely in relation to the mainshaft center.

Driveshaft Hub

The next piece of the adaptor we will talk about is the steel hub. Along with the bushing, this is what locks the flywheel in position on the motor driveshaft. The face of the hub looks like the flywheel end of the IC engine's crankshaft, which it duplicates.

In order to design the hub, I have the customer send me the flywheel and one flywheel bolt from the car. I measure the flywheel and draw a full-scale sectioned side view of it on my computer, using a computer aided design (CAD) program. I then draw in the hub, which may have a projecting diameter to accurately locate the flywheel. (In some cases, the outside diameter of the hub itself is the locating surface.) The drawing includes the flywheel bolt hole circle, and any provisions for a mainshaft pilot bushing or bearing. Also shown are the number of flywheel bolts, their thread size and pitch, and the number of degrees between the holes in the bolt circle.

All of these items added together give us a duplicate of the original crankshaft end, which makes up half of the system that mounts the flywheel on the motor shaft. In addition to the flywheel bolt holes in the hub, there are four to six holes, drilled and counterbored for small socket head cap screws. They are arranged in a circular pattern similar to the flywheel bolt circle. These holes match up to holes on the bushing, as we will see later.

On the opposite side of the hub, away from the flywheel, a large tapered hole is bored. The depth of the hole and the degree of taper matches the length, degree of taper, and end diameters of the bushing, which locks the flywheel and hub to the motor shaft.

Bushing

The tapered bushing is a short piece of steel with ends of different diameters. A hole the size of the motor driveshaft runs through it from one end to the other. A suitable keyway slot is cut the length of the shaft hole for a piece of square steel key stock which will fit a matching slot on the driveshaft.

On the side of the bushing opposite the keyway, a narrow slit is cut through the bushing along its entire length. Starting on the small diameter end, from four to six small holes are drilled through the length of the bushing, and then tapped to give them threads for most of their length. The spacing and diameter of these holes matches that of the holes drilled and counterbored in the hub earlier.

To install it, the bushing is slipped over the motor shaft and key, then the hub is placed over the bushing. The small socket head screws are inserted through the holes in the hub and threaded into the tapped holes in the bushing. As the bushing is pulled into the hub, the taper tightens and causes the slit to close, locking the bushing to the shaft. At the same time, the tapered surfaces of the hub and bushing are being locked together by the tension.

After the screws are tightened a little more than hand tight, the hub/bushing assembly can be removed only with a heavy-duty puller, or by hammering on the loosened set screws to break the taper lock.

Fill In the Blanks

With the flywheel and the hub/bushing assembly drawn on the computer screen, I next draw in the side view of the profile plate. The surface of the profile plate which contacts the mating surface of the transmission is parallel to the furthest surface of the flywheel. I call the distance between these two surfaces the "magic distance." This number is obtained by measuring from the same surface of the flywheel to the mating surface of the engine block before the flywheel is removed from the IC engine.

Once the transmission side of the profile plate is drawn in and placed at the magic distance, the motor side of the plate is drawn in parallel to it at the proper thickness of the plate. The motor is drawn in next, located by a predetermined point in the bushing and by the end of the motor shaft. Depending on the length of the hub and the thickness of the profile plate, there is a gap between the plate and the motor of aproximately 5/8 to 2 3/4 inches (16–70 mm). This gap is filled by the motor ring.

Motor Ring

The motor ring allows us to use a thin, light, and easy-to-make profile plate. For adequate rigidity, the plate should be at least 5/8 inch (16 mm) thick. The resulting gap to the motor is filled with this thick ring. The ring is much smaller across than the plate, so a thick ring is lighter and cheaper than a thick plate would be. Also, it's round, which is much easier and cheaper to machine in thick material than the irregular shape of the plate would be.

The motor ring has a locating projection or recessed diameter that matches a recess or projection on the motor, and a locating projection that matches a recess on the profile plate. There are four through-holes counterbored to suit the cap screws which hold the ring to the motor, and four threaded holes for the bolts that hold the profile plate to the ring.

Put It All Together

So let's see how this all works. The locating projection of the motor is concentric with the centerline of the motor shaft. It fits into the recessed diameter of the motor ring, which is concentric with the locating projection on the other end of the motor ring. This projection fits into the locating recess of the profile plate, which is concentric to the center point of the mainshaft. This is the same center point that was used to locate the dowels. They, in turn, secure the motor/adaptor assembly on the transmission with the

motor driveshaft and the transmission mainshaft on the same centerline within 0.001 inch (0.025 mm).

This is a brief overview of what's involved in designing a motor adaptor for an EV. I did not talk about the machinery involved, or the skill necessary to operate the machinery to get the precision needed.

The success or failure of a home built adaptor is dependent on the skill of both the designer and the machinist building it, and how much time they are willing to put into doing it. Now that I have designed dozens of them, and have the tooling and CAD program, it takes me about twelve hours to take all the measurements, do the drawings, and check the math. It takes the machinist another twelve or more hours to build the parts.

I would like to dedicate this article to the memory of John Wasylina. He built adaptors for most of the early EVs in the San Francisco Bay area (which was one of the early hotbeds of hobbyist conversions), using the taperlock system he developed. He taught me most of what I know about adaptor design.

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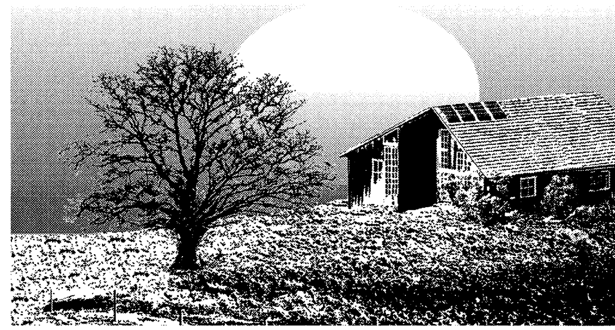

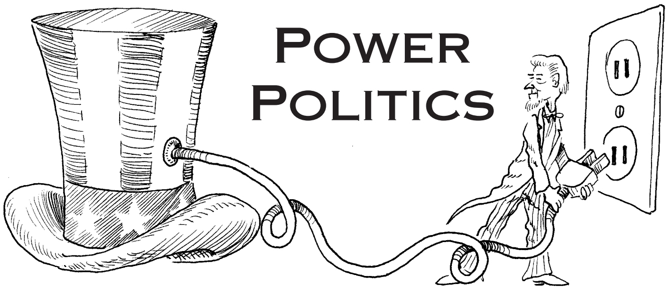

U.S. Energy Policy Up for Grabs

Michael Welch

There is so much going on nationally with RE that it makes my head swim. One very important project is an annual opinion poll on how U.S. citizens want tax dollars to be spent on energy programs.

I have reported on these surveys in years past. Once again it is quite evident what a majority of the public wants the U.S. government to do with energy policy. Unfortunately, our elected and appointed representatives continue to ignore our opinions.

America Speaks Out

America Speaks Out on Energy: Funding Priorities, Electric Utility Restructuring, and Tax Incentives was conducted for the Sustainable Energy Coalition by Research/Strategy/ Management, Inc. Between May 10th and 18th, 1999, 1,029 adult Americans were surveyed. The survey margin of error was ±3.0 percent.

There is a malaise among the general public toward RE issues in the U.S., and renewed publicity efforts by the nuclear power industry. In spite of this, the findings reflect even higher levels of support for sustainable energy programs than were measured in the Coalition's earlier annual polls. The support cuts across all political, gender, age, geographic, and income categories.

Normally I am hesitant to load up my columns with statistics, but how else am I going to give the full sense of something like a survey? Stats can be inaccurate or even manipulated toward a predisposed conclusion if methods are flawed or end results are taken out of context. But the Sustainable Energy Coalition uses a polling firm that often works with right-leaning, Republican causes. That should eliminate any claims of liberal bias.

Renewable Energy R&D

62 percent of Americans would give the highest priority to funding the U.S. Department of Energy's (DOE) renewable energy and energy efficiency research and development (R&D) programs. 31 percent of respondents selected nuclear power as the first R&D program that should be subject to budget cuts, followed by fossil fuels (21%). Only 5 percent would cut funding for energy efficiency R&D, while just 9 percent would reduce the renewable energy budget.

Ironically, recent votes by the House Science Committee and Senate Appropriations Committee would allocate federal energy dollars in a manner completely at odds with the public's preferences. According to the American Solar Energy Society, the House Science Committee has considered and passed out of committee two bills, HR 1655 and HR 1656, which propose funding ceilings for DOE civilian R&D and commercial applications programs respectively.

The ceilings will apply to the 2000 and 2001 budgets (all years refer to fiscal year budgets). In most cases, the DOE's energy efficiency and renewable energy programs would be capped at or below 1999 levels. Under the proposed legislation, however, funding for nuclear and fossil fuel research would not be restricted to 1999 levels.

Representative Mark Udall is offering an amendment to each bill to increase the funding ceilings for energy efficiency and renewable energy. The Udall amendment to HR 1655 will increase the ceiling by US$160.1 million for 2000 and US$225.6 million for 2001, increases of 15 percent and 20 percent respectively. The Udall amendment to HR 1656 (affecting a much smaller group of programs) will increase the ceiling by US$10.6 million for 2000 and US$10.1 million for 2001, increases of 40 percent and 37 percent respectively.

What can we do to get the government to do the right thing? Contact your representatives and tell them of the predicament now being faced by federal renewable energy and energy efficiency programs. Encourage them to support efforts of the Renewable Energy Caucuses (both the House and Senate) to ensure that adequate funding for sustainable energy technologies is provided in the 2000 and 2001 budgets.

Deregulation

78 percent of respondents support a requirement that utilities generate 10 percent of their electricity from solar, wind, geothermal, and biomass, as part of federal electric utility restructuring legislation. 59 percent favor a 2 to 3 percent surcharge on utility bills to support energy efficiency, low-income energy assistance, and renewable energy R&D programs. 89 percent of Americans feel that electricity providers should be required to tell their customers the type of fuel being used to generate electricity as well as the type and amounts of air pollutants being emitted.

A lopsided majority (76%) was clear about who should pay for nuclear power. They believe that utility shareholders, not utility customers, should bear the uneconomic costs of these plants under deregulation. Neither the White House nor anyone in Congress has introduced a utility restructuring proposal that reflects the public's preferences.

What can we do about this? Write the White House, and learn more about the Critical Mass R.A.G.E. (Ratepayers for Affordable Green Electricity) program. See *HP67,* page 88 for more information.

Tax Incentives for Energy
80 percent favor tax incentives to increase the use of renewable energy for the production of electricity either strongly (45%) or at least somewhat (36%). The survey polled citizens about incentives for the purchase of automobiles that are at least twice as energy efficient as the average new car. 77 percent support incentives either strongly (46%) or at least somewhat (31%).

83 percent support tax incentives for the purchase of new homes that are at least 30 percent more energy efficient than the average new home. Finally, 84 percent of those surveyed believe tax incentives should be made available to encourage the purchase of home heating and cooling systems that are at least 30 percent more efficient.

Update on Mobile Chernobyl
Soon after deadline for my column in *HP71,* Public Citizen published a report, *The Nuclear Industry: A Cash Cow for Congress.* It adeptly explains why nuclear power is still a factor in U.S. energy policy. It's really no mystery; the nuclear industry gives a *lot* of money to politicians to further its cause. Forty-nine Congressmembers received campaign contributions from the nuclear industry in 1998. Of these, only eight voted against the Mobile Chernobyl bill. See the table for the dirty details.

And as the 1999 Mobile Chernobyl bill comes up for a vote, the contributions keep rolling in. Public Citizen analyzed the political action committee (PAC) contributions from corporations, labor groups, and other organizations who are members of the Nuclear Energy Institute (NEI), the lobbying arm of the nuclear industry. Here are a few excerpts from the Public Citizen report:

"...these groups gave almost US$15.5 million dollars to current members of Congress in the 1998 election cycle."

"The leading recipients of contributions from the nuclear industry are those representatives who supported HR 1270, a similar bill in the last Congress. Meanwhile, the political parties have accepted US$3.7 million in soft money from NEI and its membership since 1997."

"Not surprisingly, there is a direct correlation between members of the House who voted with the nuclear industry and the industry's campaign contributions."

Nuke Train
One of those NEI members is the nuclear reactor manufacturer General Electric, which also happens to own NBC. The network was planning to run a TV mini-series called *Atomic Train,* about a runaway Idaho-to-Denver train carrying a nuclear weapon and nuclear waste. When corporate bigwigs found out that their network was planning to run a program that might not show nuclear waste in a completely safe manner, things changed in a flash. All references to nuclear waste were changed to "hazardous waste."

In the original promos for the movie, star Rob Lowe said, "it

Largest NEI PAC Contributions to the 106th Congress (1998)

State	*Congressmember*	*HR 1270**	*Total*
AK	Young, Don	Supported	$52,000
AL	Riley, Bob	Supported	$40,500
AL	Aderholt, Robert	Supported	$39,000
AZ	Hayworth, J. D.	Supported	$43,056
CA	Bilbray, Brian	Supported	$63,954
CA	Lewis, Jerry	Opposed	$56,000
CA	Hunter, Duncan	Supported	$51,600
CA	Cunningham, Randy	Supported	$50,500
CA	Rogan, James	Supported	$48,749
CA	Packard, Ron	Supported	$42,230
CA	Tauscher, Ellen	Opposed	$41,750
CA	Sanchez, Loretta	Opposed	$39,700
CT	Johnson, Nancy	Supported	$44,609
GA	Norwood, Charlie	Supported	$50,764
GA	Linder, John	Supported	$41,250
IL	Hastert, J. Dennis	Supported	$66,641
IL	Shimkus, John	Supported	$46,106
LA	Tauzin, W. J.	Supported	$60,000
MA	Moakley, John Joseph	Opposed	$40,050
MD	Hoyer, Steny	Supported	$43,000
MI	Dingell, John	Supported	$111,632
MI	Bonior, David	Supported	$49,500
MI	Knollenberg, Joe	Supported	$46,644
MO	Gephardt, Richard	Opposed	$73,232
NJ	Pallone (Jr.), Frank	Opposed	$47,100
NM	Skeen, Joe	Supported	$54,672
NY	Towns, Edolphus	Supported	$41,950
OH	Sawyer, Thomas	Supported	$51,450
OH	Brown, Sherrod	Supported	$48,969
OH	Oxley, Michael	Supported	$47,500
OH	Hobson, David	Supported	$38,750
PA	Murtha, John	Supported	$75,450
PA	Klink, Ron	Supported	$70,841
PA	English, Phil	Opposed	$44,621
SC	Spratt (Jr.), John	Supported	$78,500
SC	Spence, Floyd	Supported	$58,250
TN	Gordon, Bart	Supported	$44,000
TX	Barton, Joe	Supported	$117,744
TX	DeLay, Tom	Supported	$73,500
TX	Hall, Ralph	Supported	$68,123
TX	Frost, Martin	Supported	$60,494
TX	Stenholm, Charles	Supported	$57,463
TX	Armey, Richard	Supported	$49,500
TX	Rodriguez, Ciro	Supported	$40,690
VA	Bliley, Tom	Supported	$80,681
VA	Moran, James	Opposed	$57,500
VA	Boucher, Rick	Supported	$40,686
VA	Davis, Thomas	Supported	$39,075
WA	Dicks, Norman	Supported	$40,500

* 1998 Mobile Chernobyl Bill

Reprinted from a Public Citizen report, *The Nuclear Industry: A Cash Cow for Congress.*

could happen." In fact, the accident originally portrayed in *Atomic Train* couldn't happen. But the danger of nuclear waste transport that caused the movie to be made in the first place is genuine, and no amount of self-censorship by General Electric and the nuclear industry can change that fact.

What to do about this? Boycott any and every GE product, and don't even think about watching their programming or supporting their advertisers. Besides that, TV can rot your brain.

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Who Controls the Power Highway?

Don Loweburg

For years, utilities have used interconnection rules and requirements as a means to limit independent generation. By making it difficult and expensive to gain access to the electric distribution system, utilities have tried to keep independent generation at a disadvantage.

Prior to the 1970s, utilities exercised a near monopoly on all generation. Only under the pressure of an oil embargo did the federal government enact legislation mandating that monopoly utilities allow independent generators access to the transmission and distribution system. However, independent generators were not free to market their power competitively. They were forced to sell it to the host utility at "avoided cost," a price significantly below retail.

Cogeneration

In spite of the handicaps imposed by burdensome interconnection requirements and low prices, independent generation has made significant inroads during the last twenty years, primarily in cogeneration. Cogeneration is electric generation that makes use of waste heat and is located at the point of use.

Since the electricity is generated on the customer's side of the meter, it has retail value. By utilizing all the energy, including the heat associated with the generation of electricity, cogeneration can compete with utility generation. Cogeneration was the first wave of the distributed generation revolution.

Tax Credits & Incentives

The oil embargo of the mid '70s was responsible for an upsurge in the use of renewable energy sources. Federal tax credits spurred solar water heating for homes and businesses. Business tax incentives created opportunities for wind farms and other large-scale renewable energy projects. These enterprises did not fare as well as cogeneration because energy prices did not escalate as expected. Further, the renewable energy farms were required to sell to the utilities.

Renewable energy's "failure" was due to market and regulatory forces, not technical issues. This was true for solar thermal too, though many tried to paint the problem as a technical quality issue. In fact, low energy prices and the end of tax incentives undermined sales, leading to the collapse of the support infrastructure. Without a support infrastructure to provide routine maintenance, the solar thermal industry "failed." Imagine if all the auto mechanics disappeared. Would we speak of the "failure" of the personal transportation industry?

Distributed Generation

Distributed generation (DG) might be loosely defined as small generation sources located at or near the point of load. The single most important aspect of DG is that it allows for self-generation. The generating party receives retail value for the power that is used on site, a far better economic return than avoided cost.

Readers of this magazine are mostly interested in renewable DG, and that's my focus here. Cogeneration is economically viable because of the added value of the heat produced during generation. In the same way, DG using photovoltaic or other renewables can be economically viable. This is due to the "distribution benefits" available because the generation is at the point of load. These benefits accrue to both the customer and the utility managing the distribution system.

For the customer, benefits include increased power reliability and quality. For the utility, benefits include peak load shaving (PV delivers power at midday, a time of peak demand, thus reducing the load on the wires and power plants) and deferral of distribution system upgrades.

Earlier I referred to the DG revolution. This paradigm shift is in large part responsible for the utility restructuring now taking place. Advances in DG technology (renewable and non-renewable) are driving this process. With increasing development of DG technologies, two related issues are coming to the fore: interconnection standards for DG sources, and regulatory questions regarding anti-competitive issues when investor-owned utilities own DG.

Interconnection Standards

Of particular interest to PV users and the PV industry are standards affecting the interconnection of inverters to utility wires, especially for inverters under 10 KW. These inverters function in systems operating under net metering tariffs in more than half the states in the USA. It is predicted that within a few years almost all the states will have this legislation enacted.

An interconnection standard (P929) is undergoing final approval by the Institute of Electrical and Electronic Engineers (IEEE). IEEE P929 represents the collaborative effort of inverter manufacturers, PV advocates, utility protection engineers, and staff at Sandia and NREL. Reference to IEEE, UL, and *NEC* standards is being included in the language of state net metering legislation. This will simplify the interconnection process for the users of small, grid-connected PV systems and the utility distribution companies that serve them.

The purpose of IEEE P929 is to create simplified and safe interconnection requirements that can be used as a national standard. Utility protection engineers and inverter manufacturers came to considerable agreement, resulting in the development of a "non-islanding" test and designation for inverters. Islanding is a condition in which an inverter continues to charge up a dead utility line. It is a major safety concern of utilities.

Underwriters Laboratories (UL) has included the non-islanding test as part of its updated listing (UL 1741) for inverters. Inverters that are non-islanding can be connected according to existing *NEC* requirements without extra disconnects required by some utilities. Trace Engineering recently issued a technical memo stating that its grid-connected inverters are non-islanding and would comply with the new UL 1741.

Implementation of this provision will reduce the cost of connecting PV systems to the grid and increase voluntary utility notification of grid-connected systems by the owners. It remains to be seen how individual utilities will implement these changes. Since many citizens regard the utilities as an extension of the evil empire, it is hoped that the utilities will see the opportunity here for some positive public relations.

Net metered residential PV systems are just one example of renewable DG. Larger installations must negotiate a morass of utility interconnection regulations. Since utilities gain income based on the volume of power sold to a customer, obstructionist interconnection requirements could be used to protect revenue.

The Fox Guards the Henhouse
There is another twist to this scenario. Though restructuring is splitting utilities into regulated distribution companies and unregulated generation companies, utility distribution companies (UDC, the regulated half) still plan to participate in DG. They argue that DG falls within the utility franchise because this generation is for the purpose of creating distribution benefits.

Utilities have in fact coined the term "grid support" for this kind of generation, a practice which serves to cloud the distinction between generation and distribution. Others—and this includes me—perceive that generation is generation, rightfully a competitive activity whether or not it has distribution benefits.

If the UDCs are permitted to engage in DG, they have unfair advantage in two ways. First, they write the rules pertaining to grid access and they can structure the interconnection requirements to unfairly favor themselves. Second, UDCs control access to information about the distribution system and can maintain an unfair competitive advantage for themselves by limiting information.

Define the Terms
One simple solution is to apply a strict definition of generation. Restructuring unbundles generation from transmission and distribution (T&D). Since T&D remains regulated, regulatory commissions could prohibit utilities from engaging in DG.

Another approach would be to extend restructuring, and unbundle distribution from the utility franchise. If this move were taken, distribution would also become a competitive, unregulated activity. Distribution and generation would be completely unbundled.

Don't Believe the Names
Interconnection and distributed generation issues are currently the subject of hearings at California's Public Utility Commission and are becoming major issues as utility restructuring proceeds nationwide. I advise caution about a number of groups already in the fray. They have names suggesting a pro DG position, though they are in fact fronts for utility efforts to control DG.

Environmental groups such as the National Resources Defense Council (NRDC) are also taking a very compromising position with respect to utilities and DG. And utilities calling for "customer choice" and "competition" ring with sardonic irony when compared to their dominant market position and past history.

Kyocera Buys Golden Genesis
This merger—the latest in a wave of mergers—is expected to be complete by late July. This event is consistent with the vertical integration now occurring in the PV industry and follows several others discussed in previous columns. IPP questions whether this level of vertical integration is healthy for the industry.

One noteworthy difference here is that Kyocera is a non-traditional player in the energy business. Other recent RE mergers have involved oil companies and utilities, firms already in the business of delivering energy to end users.

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To Ground or Not to Ground: That is *Not* the Question (in the USA)

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

"Even most 12 volt PV systems shall be grounded in some way," sayeth ye *National Electrical Code (NEC).* This Code Corner will begin with the code requirements for a PV system from the ground up.

Subsequent articles will discuss the code requirements for PV hardware on the roof and for the components in between. The terminology, the whys, and the hows of grounding PV systems will be addressed. Proper grounding will enhance safety (both user and equipment), improve performance, and may even reduce costs. Article 250 (Grounding) was completely revised in the 1999 edition of the *NEC* and references to Article 250 will refer to the new edition.

Why?

Research and experience have indicated that both grounded and ungrounded electrical systems can be safe. Europeans have a 100 year tradition of operating ungrounded electrical power systems, and European codes reflect this. The European Community also makes use of double-insulated components and electronic ground-fault detectors in many applications.

Reports in the U.S. have indicated that on ungrounded DC electrical systems (non-PV) used by electrical utilities, when a ground fault occurs that is undiscovered or unrepaired, a second ground fault will frequently occur for the same reason within two weeks. Double ground faults create problems because overcurrent devices may not sense them and may not offer protection. The utilities always rely on extensive electronic ground-fault detectors in their ungrounded DC electrical systems.

In the United States, the arguments for and against grounding were carried out over several decades as the *NEC* was being developed, just before the turn of the century. Unlike the Europeans, the U.S. decided to require the use of grounded systems. For those who want to achieve a good understanding of the subject of grounding, the *NEC Handbook* and the International Association of Electrical Inspectors (IAEI) *Soares Book on Grounding* are recommended (see Access). The IAEI book even gives some of the history of grounding requirements in the U.S.

Electrical systems in the U.S. (including PV systems) are generally solidly grounded to limit the voltage with reference to ground during normal operation, and to prevent excessive voltages due to surges from lightning or unintentional cross connections with higher voltage lines.

In PV systems, the modules are usually mounted in high, exposed locations where they are prone to picking up induced surges from nearby lightning strikes. Utility-interactive inverters are also subjected to surges on utility power lines. In addition, systems using PV power to run computers with hardwired modems are subject to surges from the telephone line. Proper grounding effectively reduces these potential problems and more.

Terminology

The term "grounded" indicates that one or more parts of the electrical system are connected to the earth, which is considered to have zero voltage or potential. The earth is used as a reference because there is so much of it, and many conductive surfaces are connected or in contact with it. Most metallic objects such as metal building frames, as well as other electrical/electronic systems (TV, telephones, etc.) are in contact with or connected to earth. In some areas, the term "earthing" is used instead of "grounding."

Plumbing (including bathtubs and sinks) used to be solidly grounded. But now it may be not connected to ground because of the use of plastic pipes and drains. When faults occur in electrical systems, those faults are frequently faults to earth (ground faults). To better understand the grounding requirements of the *NEC,* it is necessary to examine several terms used in conjunction with grounding.

A *grounded conductor* is a conductor that normally carries current and is connected to the earth. Examples are the neutral conductor in AC wiring and the negative conductor in many DC systems. Note that some DC systems such as telephone systems connect the positive conductor to ground rather than the negative conductor. A system is a "grounded system" when one of the current-carrying conductors is grounded.

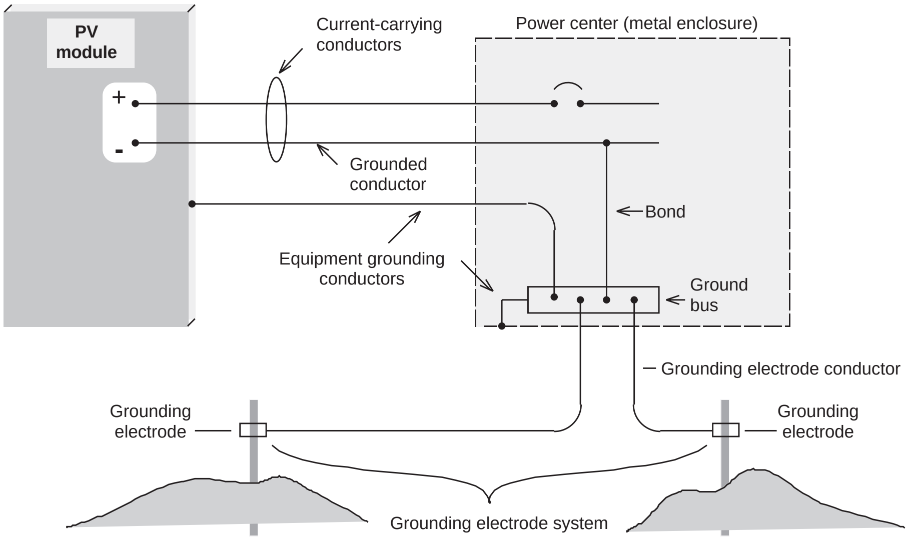
An *equipment-grounding conductor* is a conductor that does not normally carry current (except under fault conditions) and is also connected to earth. It is used to connect the exposed metal surfaces of electrical equipment together and then to ground. Examples are the bare conductor in non-metallic sheathed cable (Romex®) and the green, insulated conductor in power cords for portable equipment. These equipment-grounding conductors help to prevent electrical shocks and allow overcurrent devices to operate properly when ground faults occur.

A *grounding electrode conductor* is the conductor between a common single grounding point in the system and the grounding electrode. Splices are not normally made in this conductor. The *common single grounding point* is a point where the grounded conductor and the equipment-grounding

conductors are connected to the grounding electrode conductor.

A *grounding electrode* is the metallic device that is used to make actual contact with the earth. There are "made" grounding electrodes, such as the common 5/8 inch diameter, 8 foot long (16 mm x 2.4 m) ground rod. Other types of grounding electrodes include metal water pipes, metal building frames, and concrete-encased cables (known as Ufers, after their inventor). Specific requirements for each of these grounding electrodes can be found in Article 250 of the *NEC.* Local codes and practices vary greatly and should be investigated to determine which types of electrodes are in common use.

Figure 1: Grounding Electrodes



Bond is a term that, as a verb, means to connect two or more points together. As a noun, it usually refers to the connection between the grounded conductor, the equipment-grounding conductors, and the grounding electrode conductor. Bonding is also used to describe connecting all of the exposed metal surfaces together to complete the equipment-grounding conductors.

A *grounding electrode system* is a system where two or more grounding electrodes are connected together. These systems are common in PV installations where there are two grounds (such as an existing one for the AC system and a new grounding electrode that has been installed for the DC system). See *NEC* Sections 250-81 through 250-86.

Figure 1 shows how the grounding components are related in a PV system.

There is Grounding and There is Grounding

***NEC* Requirements**

The *NEC* establishes requirements for nearly all field-installed electrical systems that are not owned and operated by a utility on utility property. For example, it covers PV systems (Article 690), cranes and hoists (Article 610), EV charging stations (Article 625), electric welders (Article 630), computers (Article 645), communications systems (commercial and amateur, Chapter 8), and most other electrical installations.

The *NEC* covers low voltage systems (less than 50 volts) in Article 720 and high voltage systems (over 75 kilovolts) in Section 110. It covers systems with zero frequency (direct current) through radio frequency (RF) systems into the gigahertz range.

Equipment Grounding

With respect to grounding, the *NEC* requires that all PV systems have equipment-grounding conductors that connect all of the exposed metal surfaces of the system to a grounding electrode (690-43). This applies to any PV system that has field-installed wiring (items like solar wristwatches and path lights are excluded), even those operating at 12 volts. As noted above, the non-current-carrying conductors may be bare (uninsulated) or covered with green insulation. They are normally routed along with the current-carrying conductors.

System Grounding

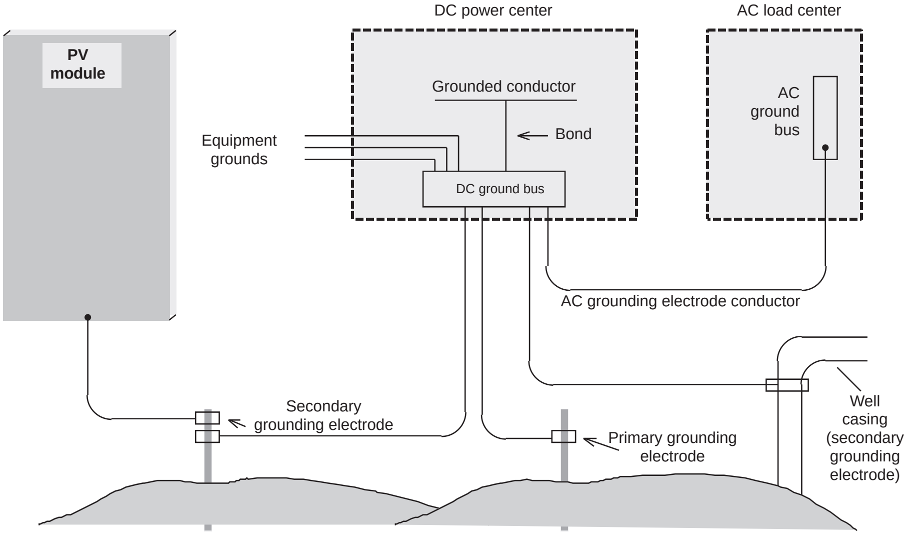
When it comes to the grounding of one of the current-carrying conductors, different rules apply. Those systems with a system voltage over 50 volts are required to be grounded by having one of the current-carrying conductors connected to the grounding electrode. The system voltage is the maximum open-circuit voltage of the system as defined in Article 690.

PV modules (crystalline silicon-based) have open-circuit voltages that increase with decreasing temperatures. At temperatures below 25°C (77°F), the open-circuit voltage will be higher than the open-circuit voltage marked on the back of the PV module. Since this system voltage is dependent on temperature, a temperature correction factor is necessary (Table 690-7). The correction factor is selected based on the lowest expected ambient temperature where the PV system is to be installed, and is used as a multiplier on the rated, open-circuit voltage of the module. At low temperatures and with high winds, or in the early morning hours, the PV module may not heat up, so the lowest ambient temperatures for the area should be used.

The calculations required by Section 690-7 and Table 690-7 of the *NEC* indicate that a nominal 12 volt PV system has a system voltage of about 27 volts in worst case, low-temperature installations. This is determined by multiplying the 22 volts open-circuit voltage at 25°C (77°F) by a correction factor of 1.25 for temperatures below -21°C (-6°F). Therefore, 12 volt systems do not have to have one of the current-carrying conductors grounded.

A nominal 24 volt system has a rated open-circuit voltage of about 44 volts at 25°C (77°F). This means that one of the current-carrying conductors must be connected to the grounding electrode when the expected lowest temperatures are below about -10°C (14°F). Temperatures below this will cause the open-circuit voltage to exceed 50 volts.

Figure 2: Multiple Grounding Electrodes



Prior to the 1999 edition, the *NEC* did not have Table 690-7, and the voltage multiplication factors were included in the instructions provided with listed PV modules. Since Underwriters Laboratories (UL) Standard 1703 for PV modules has not yet been revised, there will be PV modules in the distribution network that have the older instructions, duplicating the instructions in the 1999 *NEC.* Either the 125 percent factor in the PV module instructions or the Table 690-7 corrections should be applied, but not both.

System Grounding of 12 Volt Systems —Other Considerations

On 12 volt PV systems and some 24 volt PV systems, the grounding of one of the current-carrying conductors is optional, as noted above. However, in Articles 230, 240, and 690, the *NEC* requires that ungrounded conductors in any electrical system have overcurrent protection and disconnects. Since a 12 volt PV system must already have equipment-grounding conductors, a grounding electrode conductor, and a grounding electrode, there is a significant cost advantage and sometimes a performance advantage to grounding the system.

With the addition of one wire (the bond shown in Figure 1), the number of disconnect poles and overcurrent devices can be cut in half since these devices are not required in the now grounded, current-carrying conductor. Since each of those disconnects and overcurrent devices has some small but measurable voltage drop, eliminating as many of them as possible will improve system performance and increase reliability.

It should be noted that most PV power centers on the market have one of the conductors grounded internally and have provisions for only single-pole overcurrent devices and disconnects. They cannot be used in an ungrounded 12 volt system.

Furthermore, low-voltage fluorescent lamps start more reliably when installed in a grounded system and inverters and other electronic devices can be installed so that they radiate less noise when one conductor is grounded.

Equipment Grounding

Table 250-122 in the *NEC* specifies the size of the equipment-grounding conductors for each circuit. The size is based on the rating of the overcurrent device protecting the circuit and ranges from number 14 AWG (2 mm^2) conductor in a 15 amp circuit to a number 3 AWG (26.7 mm^2) equipment-grounding conductor in a 400 amp circuit.

Recent research has determined, however, that the equipment-grounding conductor for PV source and PV output circuits must at least be able to handle 125 percent of the PV short circuit currents. In most cases, this indicates that the equipment-grounding conductors for PV source circuits and PV output circuits must be the same size as the current-carrying conductors. These are sized at 156 percent of the module short-circuit current. Proposals for the 2002 *NEC* will be submitted to reflect this requirement.

Of particular interest to PV installers is Section 250-122(b) of the *NEC.* It states that if the current-carrying conductors have been oversized to minimize voltage drop, then the equipment-grounding conductors must also be oversized in the same proportion. But the grounding conductors never have to be larger than the current-carrying conductors. Oversized conductors (above minimum ampacity requirements) are frequently used on long circuits between the PV array and the charge controller to reduce voltage drops in these lines. Table 8 in Chapter 9 of the *NEC* shows the cross sectional area of different sized conductors, and the calculation is straightforward.

Oversizing the equipment-grounding conductors is required by the *NEC* to ensure that overcurrent devices function properly during ground faults. Section 250-122(a) says that the equipment-grounding conductors do not have to be larger than the current-carrying conductors.

In summary, the equipment-grounding conductor should be as large as the current-carrying conductors in PV source and PV output circuits. In other circuits, follow Table 250-122.

Equipment that must be connected to the equipment-grounding system includes the exterior metal surfaces of PV modules, power centers, charge controllers, inverters, switchgear, outlet boxes, and overcurrent devices. Equipment listed to UL standards will have properly marked connections and instructions for connection of the equipment-grounding conductors.

The equipment-grounding requirement in renewable energy systems is usually met by using a separate conductor run with the current-carrying conductors. If the system uses metal conduit (and many commercial systems do), then the conduit can serve as the equipment-grounding conductor when used with listed fittings.

The connection of the equipment-grounding conductor can run from module frame to module frame and then to the switchgear and power center. The order of the connections is not critical and multiple connections or parallel connections do not cause problems. Each equipment-grounding conductor may also be run from the metal surface being grounded to a central point like the power center.

The connections and wiring for the equipment-grounding conductor must be continuous to allow fault currents to properly operate overcurrent devices. Removal of a piece of equipment for servicing must not interrupt the equipment-grounding system for other equipment.

Generally, module frames are made of anodized aluminum. The anodized coating or aluminum oxide that forms on aluminum surfaces is a relatively good insulator. This is why listed PV modules have a special point marked for connecting the equipment-grounding conductor. A stainless steel screw is usually supplied which helps to ensure a good electrical connection.

It should be noted that while the anodized surface insulation on PV modules makes it hard to get a good equipment-grounding connection, the aluminum frame is still exposed metal. If it is not grounded, it can produce an electric shock when ground faults occur. These can occur between the current-carrying parts of the module and the frames, or when the frames are inadvertently energized by other power sources.

Aluminum PV module frames do not stay well grounded when they are only bolted to the metal mounting stands. If the UL listing allows, and the module manufacturer provides special parts and instructions, some PV modules may be grounded through the mounting bolts to the frame. The *NEC* prohibits the earth from being used as the sole equipment-grounding conductor, so bolting the PV modules to a metal stand that is inserted in the ground does not meet the requirements for a safe installation unless a separate equipment-grounding conductor is used from the frame to the main grounding point or electrode.

The *NEC* requires that all conductors for a given circuit be routed together in the same cable or conduit. An exception is the equipment-grounding conductor for DC circuits. When secondary grounding electrodes are used and they are bonded to the primary grounding electrode (as described below for surge protection) the bonding conductor may become an equipment-grounding conductor and should be sized appropriately. In this case, the DC equipment-grounding conductor may not be grouped with the current-carrying conductors.

Grounding the Current-Carrying Conductor

The connection between one of the current-carrying conductors and the grounding electrode conductor is made only at one point in the system. This is known as the system ground. This single-point connection is usually made in a power center and is shown as the bonding conductor in Figure 1. If this connection is inadvertently made in more than one place (for example, at the PV modules and in the power center or at the load), then unwanted currents will flow in the equipment-grounding conductors. These unwanted currents may cause inverters and charge controllers to be unreliable and may interfere with the operation of ground-fault detectors and overcurrent devices.

The use of RV and automotive electrical appliances and audio gear sometimes causes problems, as does the use of DC-powered radio and telephone equipment. Much of this equipment operates at 12 volts DC, with chassis and antenna ground connections that are common with the negative DC power conductor. It is pretty easy to get the negative DC conductor connected inadvertently to ground in two or more places when using these types of electrical devices.

The *NEC* also requires that equipment-grounding conductors be used with these appliances to ground the exposed metal surfaces. It becomes difficult to do this with a third conductor in a way that does not result in multiple point connections between the negative, current-carrying conductor and the grounding system. Solutions to minimize the problems include non-metallic enclosures to isolate the grounded chassis and ground-isolated antenna connections.

Listed power centers and disconnect switches usually have a provision for the single-point connection. In most DC power centers and AC load centers, the connection is automatically made when all equipment-grounding conductors, the negative conductors, and the grounding electrode are tied to a single, grounding bus bar which is also bolted to the metal enclosure.

When using standard, fused safety switches for disconnects throughout the system (PV array and subarray, battery, etc.), an insulated bus bar usually must be added. This is used to make the connections for the unswitched, grounded conductor running through the switch enclosure or subpanel.

There is frequently a bus bar supplied for the unswitched conductor. But this bus bar is sometimes grounded to the enclosure, presenting the opportunity for an inadvertent second grounding of the conductor that is intentionally grounded elsewhere in the system. Insulated, or ungrounded, bus bars should be used in these devices to prevent that second ground connection.

Grounding Electrode Conductor

The grounding electrode conductor (also known as the ground wire), is usually a single-conductor bare wire (it can also be insulated—color is not specified). It connects a grounding bus bar in a power center or another disconnect device to the grounding electrode (also known as the ground rod).

In the 1993 and earlier editions of the *NEC* this ground wire had to be the same size as the largest conductor in the DC system. In the 1996 *NEC* a number of exceptions, when met, allowed smaller conductors to be used. There are jurisdictions throughout the country that still are applying the 1993 and earlier versions of the *NEC* so some inspectors may require the larger conductors.

If there is only one conductor connected to the grounding electrode, then Section 250-166 of the 1999 *NEC* allows DC grounding electrode conductors as small as number 6 AWG (13 mm^2) copper to be used. Appropriate mechanical

protection is required where this conductor may be subject to physical abuse. However, if multiple conductors are connected to the grounding electrode, a grounding electrode conductor as large as the largest conductor in the DC system must be used.

Multiple connections to the grounding electrode conductor refer to connections from the power system and do not refer to telephone, TV, cable, or other types of communications grounds. Multiple connections to the grounding electrode may also occur when several ground rods are bonded together to form a grounding electrode system, and when metal water pipes or well casings are bonded to the ground rod. Multiple connections are also common where DC and AC grounding electrode conductors are connected to the same ground rod. Several equipment-grounding conductors tied to the ground rod also nullify the use of a small grounding electrode conductor.

The reasoning behind not allowing a small grounding electrode conductor is this: if more than one conductor is connected to the ground rod, some of those conductors may be required to carry high fault currents. If only one conductor is connected to the ground rod, then the other properly sized and connected conductors in the system will carry the fault currents, and the smaller conductor to the ground rod will only be required to stabilize the system voltage with respect to earth. Only in lightning strikes and inadvertent connections to high voltages will the grounding electrode conductor be required to carry high currents. There are similar requirements and allowances for the AC grounding electrode conductor.

Practical Considerations

How then, can the system be connected so that a small equipment-grounding conductor can be used? One method is to designate a single grounding bus bar in the system. This bus bar is usually found in listed DC power centers. All equipment-grounding conductors should be connected to this bus bar. If there are multiple grounding electrodes in the system, the secondary electrodes should all be connected to this bus bar to complete the grounding electrode system.

If there is a requirement to provide a single-point ground for the AC portions of the system, then the grounding electrode conductor from the AC part of the system should be tied to this bus bar. Finally, the smaller (as allowed by the *NEC*) grounding electrode conductor can be connected from the grounding bus bar to the primary grounding electrode conductor. Figure 2 demonstrates these connections where the DC grounding electrode conductor is larger than the AC grounding electrode.

While this method meets the requirements of the *NEC,* it may not provide the best protection against lightning damage. Running all grounding conductors to a common point inside the building may increase the potential for damage from nearby lightning strikes.

In high lightning areas, it may be preferable to “bite the bullet” and use the larger grounding electrode conductor from the power center to the ground rod. Then secondary grounding rods and pipes and metal well casings can be connected directly to the primary grounding electrode without coming into the building. Equipment-grounding conductors from the PV modules may also be run directly to secondary or primary grounding electrodes providing additional surge protection.

Each of the grounding electrodes described below, where used as a primary electrode, has a different requirement for the size of the grounding electrode conductor. See *NEC* Sections 250-66 (AC) and 250-166 (DC). If the requirements for the AC and DC grounding electrode conductors are different, the larger of the two should be used for any common conductor. The common grounding point should be associated with the largest required grounding electrode conductor.

Grounding Electrodes

In Section 250-50, the *NEC* considers metal building frames that are in contact with the earth and metal water pipes connected to the earth to be the preferred grounding electrodes. Unfortunately, wood frame buildings, plastic pipes, and plastic sleeves on copper pipes make these options frequently unavailable to the renewable energy user.

The *NEC* describes commonly available grounding electrodes, such as “made” electrodes (the common 8 foot (2.4 m) ground rod), concrete encased cables or electrodes, and ring electrodes which consist of buried conductors encircling the building. Made grounding electrodes are listed by UL and are connected to the grounding electrode conductors with clamps that are listed for this purpose. If the clamps are to be buried, they should be listed and marked for such use.

As a primary grounding electrode, the ground rod must be driven into the earth to a depth of at least 8 feet (2.4 m). Angles of no more than 45 degrees away from vertical are allowed where the ground is rocky. If these conditions cannot be met, then a second rod or one of the other grounding electrodes must be used to supplement the primary electrode. Best performance will be achieved if the second electrode is more than six feet (1.8 m) away.

In some areas of the country where homes are built on concrete slabs, a grounding electrode is buried in the concrete slab. This usually works better as a grounding electrode than an eight foot (2.4 m) ground rod.

Summary

Equipment and system grounding are important details in a renewable energy system. They reduce the potential for electrical shock and allow the system to respond properly to ground faults. Proper application of the *NEC* requirements for grounding will result in safer systems, higher levels of performance, and reduced costs. The requirements for PV systems are generally the same as the requirements for other electrical power systems.

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems within the requirements of the *NEC,* feel free to call, fax, email, or write me at the location below. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multi-program laboratory

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Wiles, J. C. and Bower, W. I., *Analysis of Grounded and Ungrounded Photovoltaic Power Systems,* First World Conference on Photovoltaic Energy Conversion, Hawaii, 1994

Bob-O Schultze

Dummy loads have a bad rap and a worse name. Calling them shunt, dump, or diversion loads doesn't sound much better. Truth is, they can be pretty smart. A bit of free hot water or a few extra degrees warmth for the batteries in winter are good deals all around. It's not exactly a free lunch, but it's close.

A Diverting Experience

Using a shunt regulator to dump power when the batteries are full is the only realistic way to regulate DC hydro and wind generators. Both types of machines have to be connected to the batteries at all times to prevent unloading and overspeeding. Overspeeding a hydro plant causes serious voltage spikes and premature wear on all the moving parts. Overspeeding a wind machine can send your blades into the next county.

With automotive type alternators like the Harris Hydro, constant battery current is required to energize the field. The field windings take battery current to make the field into an electromagnet. Once the alternator is spinning, the field will energize itself. But if you take away the battery, the alternator will speed up, producing a higher voltage, which is fed back into the field, producing a higher voltage, etc. A 12 volt alternator can easily put out 120 volts. Reconnecting it to the battery would cause a serious and potentially dangerous voltage spike in the system.

Shunt Regulation

There are two types of shunt regulators. Pulse-width modulation (PWM) regulators use transistors to turn the dummy load on and off very fast. As the batteries approach the set regulation voltage, the on times or pulses get shorter than the off times. At full regulation, the charging pulse is on only long enough to keep the battery at a given voltage. Some regulators hold the batteries at that voltage for a set period of time, called the absorption phase, and then allow the batteries to come down to a lower voltage, called the float voltage.

Connect/disconnect regulators will switch the dummy load on at the regulation voltage and back off at a lower voltage. The voltage difference between on and off is called the hysteresis. I call it slam bang charging. Either type of shunt regulator will keep your batteries full and your charging sources under control. The choice of which to use can be a factor of price, convenience, opinion, and whether you are dumping the power as AC or DC.

Et Tu, PV?

Can we use shunt load regulation on a PV system as well? It is used that way in many hybrid systems such as PV/Hydro, PV/Wind, and PV/Wind/Hydro (go ahead, flaunt it!). In a system with only PV, however, I generally don't recommend it. PVs don't overspeed, so they are pretty easy to regulate. There are some very good listed series-type regulators on the market these days. A good series PWM regulator is reliable, easy, and cheaper to set up than a shunt regulator. Like anything else, there are exceptions to the rules. Call your local Wrench for help.

AC or DC?

Diverting DC power makes good sense if you don't have a lot of it. It's also the way to go if you have a small inverter or none at all. The good news is that you can use a PWM shunt regulator, which tends to get the most years out of a battery bank. The bad news is that you are severely limited in your choice of dummy loads.

High wattage, low ohmage resistors are hard to find in configurations that will divert a wattage roughly equal to your charging sources. DC water heating elements are expensive and not available to fit many water heaters. You can use AC water heating elements to dump DC, but the resistances are high, so you won't shed much power.

These elements are designed for 120 or 240 volt systems and have a high resistance. The current they can absorb decreases as you lessen the voltage (check it out with Ohm's law), and they just don't do very much

for you at 12 or 24 volts. For example, a 1,000 watt element designed for 120 volts will have a resistance of 14.4 ohms. In a 24 VDC system with a regulation voltage of 28.8 VDC, that element will only divert 2 amps. Big deal.

Shunting AC power works best if you have enough excess power to do something wonderful like provide some of your hot water. Resistive loads designed to eat 120 or 240 VAC are everywhere and inexpensive. Water heating elements and space heaters are readily available in many wattage ranges. You need to use the connect/disconnect type of regulator when switching AC loads.

Worried about your inverter being large enough to run the dummy *and* your other loads? It's a moot point. If your batteries are full enough to require regulation, you likely aren't using the inverter for anything much anyway. If you do turn on a big load, the battery voltage will soon drop enough to shut the dummy off.

The Dummy Load

The best and most reliable shunt loads are resistors. Water heating elements and space heaters are just big resistors. Light bulbs are resistors too, but I can't recommend them. Remember Murphy's Law? "Anything that can go wrong, will go wrong, and at the worst possible moment." In other words, your light bulb dummy load will burn out an hour after you leave for Christmas week at Grandma's!

The best resistor for a shunt load is a water heating element. Who doesn't use hot water? These are available in both 120 and 240 VAC models from 1,000 to 4,500 watts. Sometimes a 240 VAC element fed 120 VAC will be just right for your diversion. Hey, it's just a resistor! My system uses a 4,500 watt 240 VAC element fed 120 VAC from the inverter. It eats about 1,075 watts, just right for shunting my Whisper 1000 wind genny.

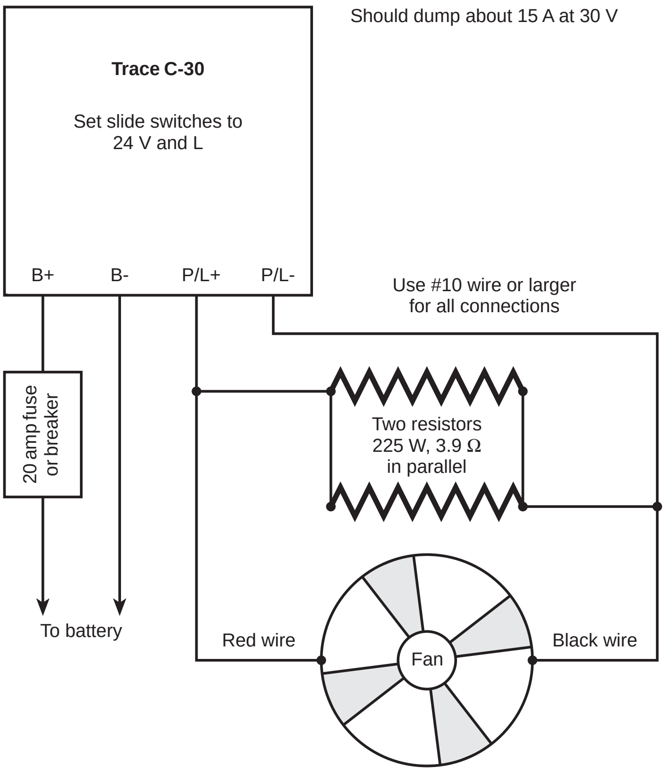
Danger, Will Robinson!

With a large charging source you may heat too much water! Run your element through a thermostat and make sure your temperature and pressure (T&P) valve works. I like to set up a second voltage sensing switch and a space heater in case the water gets too hot and the thermostat cuts the power. Setting your regulation point 0.1 to 0.2 VDC higher on the second regulator works fairly well.

Shunting DC

Shunting DC is straightforward. You need a voltage sensing switch (VSS) and a dummy load capable of dumping the full output of the charging source without burning up. Use Ohm's law to calculate the resistance and the power-handling capability of the dummy.

Shunting to DC loads with a Trace C-30



For example, say we need to divert 10 amps from a hydro plant charging a 24 volt battery system. First, choose your regulation point. Let's assume 28.8 volts. We use the formula:

$$R = E \div I$$

where R is resistance in ohms, E is potential in volts, and I is current in amps. This yields 28.8 V ÷ 10 A, or 2.88 Ω, in our system.

To figure the wattage value for our resistor, use the formula:

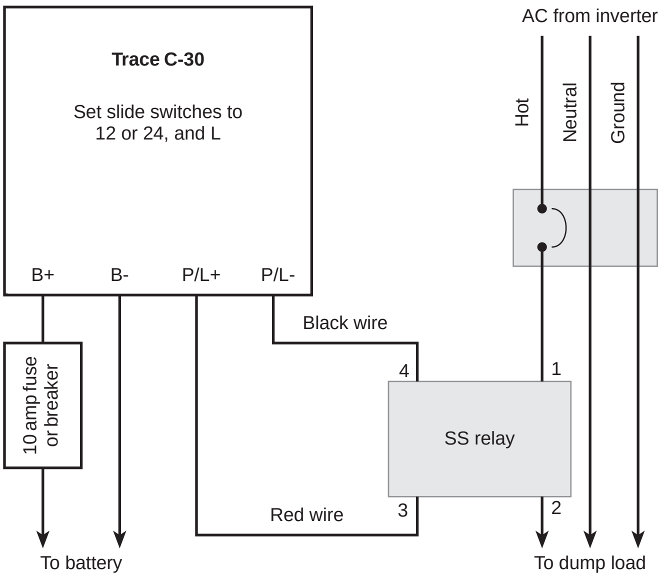
$$P = E \times I$$

where P is power in watts, E is potential in volts, and I is current in amps. So 28.8 V x 10 A = 288 W. We need at least a 288 watt resistor with a resistance of 2.88 Ω. The voltage sensing switch can be either a PWM type such as the Trace C-40 or AEE's Enermaxer, or a slam bang like the Trace C-30, Photron Simple Switch, or a homebrew.

Shunting AC with Trace SW Inverters

The Trace SW series inverters have three small voltage-controlled relays built in. Use them to control the coil of a larger relay capable of handling the current you need to dump. I prefer a solid-state relay such as Continental Industries S505-0SJ625-009. It has a

Shunting to AC loads with a Trace C-30



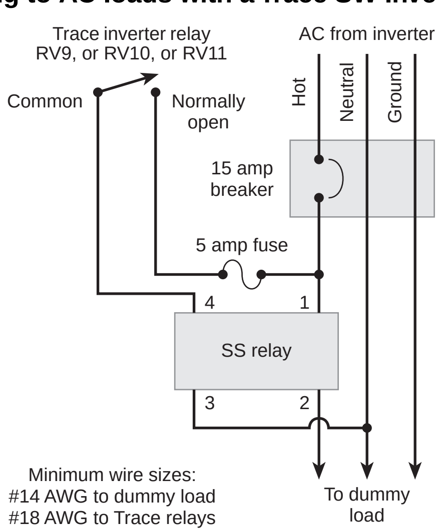
control rated from 90 to 280 VAC and contacts rated at 25 A from 24 to 330 VAC. That's plenty of range and headroom. See the schematic for details.

Shunting AC with Other Inverters

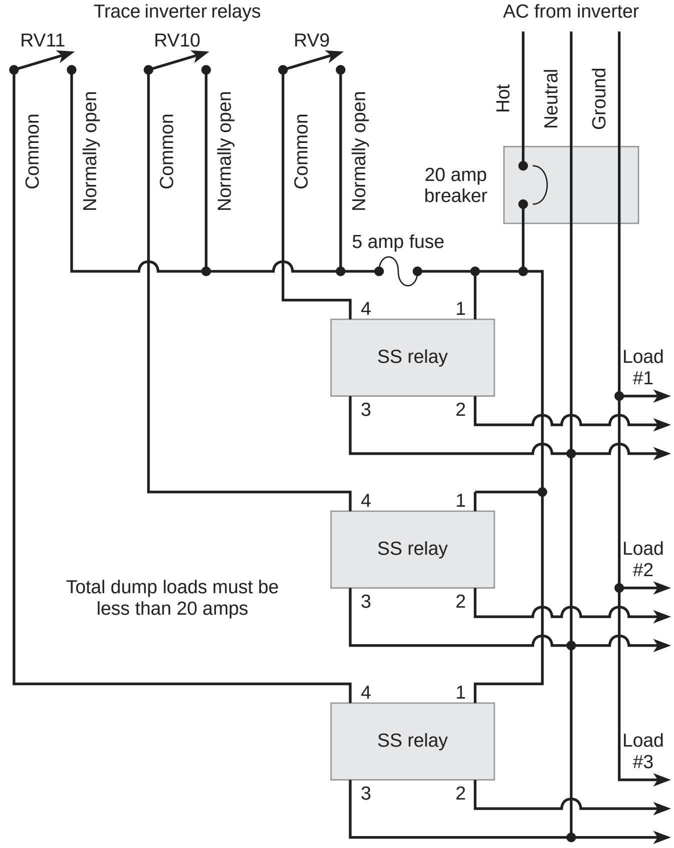
This works the same as shunting with the Trace SW, except that you'll need an external VSS and a relay with a DC-rated coil. If you want to use a solid-state relay, Continental makes the S505-0SJ625-000. It has the same 25 A and AC voltage rating on the contacts, but the control is 3 to 32 VDC. Your favorite renewable energy dealer can get these relays for you.

Any relay, and its wiring, needs to be mounted in a UL approved enclosure. The solid-state relays need to be mounted on a heat sink as well. I've found that mounting them directly to the back of a 6 by 6 by 4 inch

Shunting to AC loads with a Trace SW Inverter



Shunting to Multiple AC loads with a Trace SW Inverter



(15 x 15 x 10 cm) metal enclosure with heat sink grease works okay up to about 10 A at 120 VAC. If your load is more than that, you must heatsink and allow for heat dissipation.

It's a Wrap

Deciding which type of regulation is the best for your system isn't a trivial decision. Nor is it often cut and dried. My advice? Talk it over with your favorite Wrench. Support your local talent.

Access

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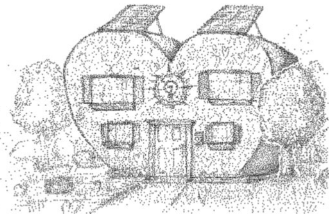
econnect@snowcrest.net
www.electronconnection.com

DC water heating elements: Alternative Energy Engineering, PO Box 339, Redway, CA 95560
800-777-6609 or 707-923-2277 • Fax: 800-777-6648 or 707-923-3009 • energy@alt-energy.com
www.alt-energy.com

Trace Engineering, Inc., 5916 195th NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-2229
inverters@traceengineering.com
www.traceengineering.com

Home & Heart



Kathleen Jarschke-Schultze

Bob-O read somewhere that people are afraid of death, electricity, and bees, in that order. I've read everything I could find on the subject of bees and beekeeping, and I find I only fear the first two. I will replace the third with "sharp knives" or "deep water."

Bee Adventurous

I went to pick up my bees on May first. I had set up my empty hives the evening before. On one hive I had painted a blue Celtic knot to help the bees identify their own hive. The two hives were next to each other on the south-facing, 18 inch high stand I had built.

The bee supplier we chose does not ship, so my friend Mona and I drove the 100 miles south to the bee ranch to pick up three packages of bees—two for me and one for her.

Each package includes three pounds of bees and a queen. They were all Italians, the most common bee in American beekeeping. The package consists of a box made of thin wooden slats with screen on the two broad sides. The queen is in her own cage, which is attached so it hangs down inside the box of bees. There is a can of sugar syrup that also hangs down into the package.

Bee Ranch

We knew we had arrived when we saw the orchard with all the bee hives. I went up and knocked on the door, and the beekeeper's wife answered. She said he was out in the trees somewhere, tending the bees, so she would get the bees for us. Okay, that seemed fine. We walked across the yard to a large metal building. The heavy door slid open and there in the warm, dark interior were our bees.

The three packages had been attached to each other with wooden lath. When you picked one up, the others came with it. The bees were buzzing quite a lot, being disturbed by the noise and light of our entry. The woman lifted the packages by the wood strips and followed me to my car. Several loose bees followed us too, the scent of the queens being irresistible to them.

I had put my station wagon's back seat down and spread a clean white sheet for our bees to rest on. When we set the packages in the car, the solo bees came in too. So we drove home with the packaged bees buzzing in the back and the strays flying around the interior of the car. Every time I would hear one by a window I would use the power control to lower the window and try to lose the bee. They were too wiley for that maneuver and would fly back to the screen of the closest package and rest there.

Hive Jive

By the time we got home it was about four in the afternoon and windy. We put our bee suits on and hived one of my packages. You can never get every bee out of the box. So after you pour out all that you can, you lay the the box at the entrance so that the remaining bees come out and enter the hive.

We then went up the road and hived Mona's bees. When I returned to my hives, all but one bee had gone into the first hive. I quickly hived the third package, not wanting to chill the queen. As with the first hive, I laid the package facing the entrance.

Earlier I had made some feeders using gallon jars with holes drilled into the lids. We placed these (one each) over the oblong hole on the inside cover of the hive, which is a lipped board placed directly over the frames. Then an empty full-sized super (basically a wooden box without a top or bottom) went over that. Finally, the outer telescoping cover was weighted down with a cinder block to make the hive weathertight.

The syrup in the feeder was a mixture of half water and half white sugar. We also placed one quart entrance feeders (Boardman type) on each hive. An entrance cleat reduces the entrances to conserve heat and allows the small number of bees (12,000) to protect their hive from intruders.

Bee Zen

The next morning I could hardly wait to check the hives. There were a couple of dead bees outside the entrance of the Celtic hive and about 25 dead bees outside the white hive. This didn't seem too bad. My plan was to wait for the first warm day and then release the queens. I had picked the packages up on a Saturday and the first warm day was supposed to be Tuesday. Bees need several days to accept a new queen. If released too soon, the hive bees might kill her.

On Sunday, I panicked. What if the queens starved before I released them? I called the bee ranch. The owner assured me that the queens would not starve, they just would not be able to start laying eggs yet. This was not an issue for me as my bees were starting out with new foundation and had to draw out the cells before the queens could begin laying anyway.

Bees are very serious about "bee space." If there is more than 3/8 inch or less than 1/4 inch, the bees will fill the


Kathleen lifts a frame out of the super.

space with propolis or spur comb. There's a little bit of slop between the frames and you have to get them evenly spaced. Since I was in a hurry to close the hives when I first installed the packages, I left too much space between two of the frames in the white hive. Now whenever I check it I have to scrape the spur comb off the inside cover.

Royal Outing

I released the queens on Tuesday as planned. They were alive and active. After I saw that, I quickly closed the hives to conserve heat. I ended up erecting a wind break next to the white hive. They became more active after that. I checked the hives one warm day. The Celtic hive has been very slow at drawing comb on the foundation. They are only working on four frames. The white hive has filled and capped several frames and is drawing comb on eight of the ten frames.

I think I need to put up a wind break by the Celtic hive. It is essential that the bees be able to keep the newly laid brood at a temperature of 92°F. With the downright cold weather we have had through May and into June, I am worried about the Celtic hive. I don't know if it can recover from this setback.

Bee Wrangling

I love beekeeping. It is totally fascinating. The more I am around the bees, the less safety gear I wear. I usually wear just a head net and gloves. Once I was up filling the entrance feeders and I felt something crawling on my stomach. I lifted my shirt and a bee flew out.

I started a bee calender in a monthly monitor datebook that had enough room on each day to keep notes. I record what the bees are doing and what I do to and for the bees. I also keep a running log of what plants and trees are blooming that the bees can utilize.

When I am out in my yard or garden and I see a honey bee, I just want to go sit and watch the hives. Sometimes I do just that. The bees come and check me out. Then they return to the hive. They are my friends, the bees.

Access

Author: Kathleen Jarschke-Schultze is thoroughly enjoying bee wrangling at her home in Northernmost California, c/o Home Power magazine, PO Box 520, Ashland, OR 97520
530-475-0830 • kjs@snowcrest.net

I recommend that you get these two books before you get your bees:

ABC and XYZ of Bee Culture, The A. I. Root Bee Library, US$30 postpaid within the U.S. The A. I. Root Company, PO Box 706, Medina, OH 44258 • 800-289-7668 or 330-725-6677, ext. 3219 • Fax: 330-725-5624 kim@airoot.com • www.airoot.com • This is an encyclopedia on the scientific and practical culture of bees, first published in 1872 and reprinted regularly since. It's the bible of bees, a big thick reference, but kind of dry reading.

Honey Bees and Beekeeping, A Year in the Life of an Apiary, Keith S. Delaplane, University of Georgia. Available from Mann Lake Ltd. (see below) for US$17.50 postpaid within the U.S. Great book, up-to-date on technique and treatments. Lots of pictures and a great read.

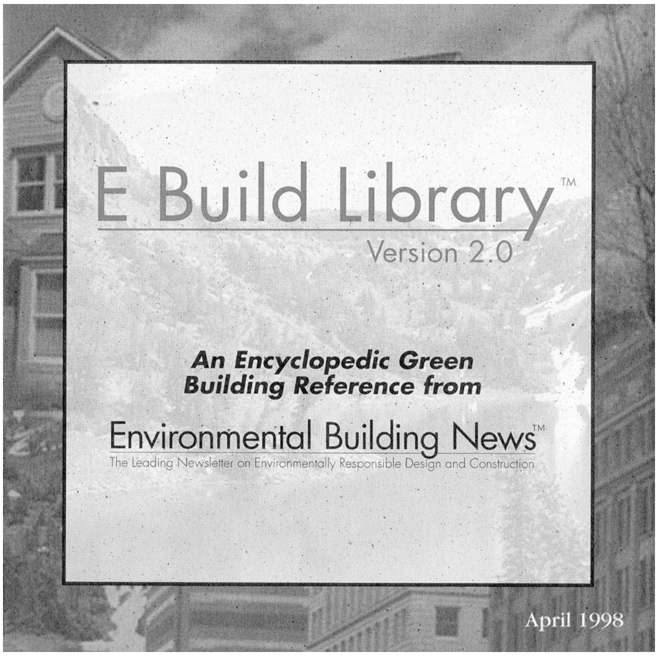
You also need to have your equipment before you get the bees. Here are several suppliers I have used:

Brushy Mountain Bee Farm, 610 Bethany Church Rd., Moravian Falls, NC 28654 • 800-233-7929 or 336-921-3640 • Fax: 336-921-2681 • sforrest@wilkes.net www.beeequipment.com

Mann Lake Ltd., 501 S. 1st St., Hackensack, MN 56452-2001 • 800-233-6663 or 218-675-6688
Fax: 218-675-6156 • beekeepr@mannlakeltd.com
www.mannlakeltd.com

Mid-Continent Agrimarketing Inc., 1465 North Winchester, Olathe, KS 66061-5881 • 800-547-1392 or 913-768-8967
Fax: 913-768-8968 • mail@mid-conagri.com
www.mid-conagri.com

Excellent Web site:
www.birkey.com/BLB/Beekeeping/besuply.html



E Build Library CD-ROM, Version 2.0:

Compiled by Environmental Building News

Reviewed by Joe Schwartz

Accessing information related to sustainable green building technologies just got easier. Brattleboro, Vermont based *Environmental Building News (EBN)* has compiled all of its back issues on a fully searchable CD-ROM. Now here's some material builders can get their hands on, and no heavy lifting!

Sustainable building has come a long way in the last decade, and *Environmental Building News* has been instrumental in fostering the movement. The monthly newsletter focuses on both residential and commercial scale projects. *EBN* is perhaps the best source for current perspectives on sustainable building systems and construction materials. While it has traditionally been more of an industry newsletter read by architects, designers, and contractors, the CD-ROM format makes it attractive to owner-builders as well.

The *E Build* CD is compatible with Macintosh system 7.1 or later, Windows system 3.1 or later, and standard UNIX operating systems. The files are in PDF format, and Adobe Acrobat Reader is included on the CD. The cost of the CD is US$149 for non *EBN* subscribers, and US$95 for current *EBN* subscribers. *EBN* accepts no advertising. All income comes from subs and sales of *EBN* products. A full set of printed back issues would cost over US$300. A 12 issue subscription is US$67 for individuals, US$127 for organizations, and US$39 for students.

E Build Library Version 2.0 includes 37 issues of *EBN,* from their first in 1992 to the November 1997 issue. All photos and graphics are included. In addition, a bibliography containing over 150 books, periodicals, and Web sites related to green building is provided. This alone is worth the price of admission. Finally, a green building products database provides access to manufacturers of environmentally responsible construction materials.

Without a doubt, what hooked me on this CD was *E Build's* search capability. Forget flipping through hard copy indexes and then trying to find the issue your buddy borrowed and never returned. The *E Build Library's* text search feature makes for super-efficient information retrieval. Type your subject into the text search box and related articles from all *EBN* back issues are listed. Each listing is hot linked to the specific article, making the information only a mouse click away.

By the time this issue of *Home Power* hits the streets, *E Build Library Version 3.0* will be out. The latest CD revision will include all of *EBN's* back issues through 1998, at the same price as version 2.0. Both the bibliography and the database from version 2.0 have also been expanded. I expect it will be just that much more of a great thing.

Access

Environmental Building News, 122 Birge St, Suite 30, Brattleboro, VT 05301 • 800-861-0954 or 802-257-7300
Fax: 802-257-7304 • circ@ebuild.com
www.ebuild.com

Reviewer: Joe Schwartz, *Home Power,* PO Box 520, Ashland, OR 97520 • 530-475-3179
Fax: 530-475-0836 • joe.schwartz@homepower.com
www.homepower.com

HAPPENINGS

CANADA

Aug 14-15, EarthFEST'99, Courtenay, BC. Exhibits and workshops on food, energy, shelter, transportation, water, waste, & sustainable communities. Non-profit event by Solar Energy Society of Canada & Canadian Organic Growers. Info: EarthFEST'99, 2050 Pine Place, Courtenay, BC, Canada V9N 3C1 • 250-334-8694 • Fax: 250-334-8695 earthfest@web.net • www.web.net/earthfest

Aug 11-14, North Sun '99. Biennial Conference on Solar Energy in high latitudes. Edmonton, Alberta. Info: Solar Energy Society of Canada, 116 Lesgar St #702, Ottawa, Ontario K2P 0C2, Canada +1-613-234-4151 • Fax: +1-613-234-2988 northsun.99@cyberus.ca www.solarenergysociety.ca

Alberta Sustainable House: Open on 3rd & 4th Saturdays (except holiday weekends), 1-4 PM, free. Cold-climate features/products based on health, environment, conservation, AE, recycling, low energy, self-sufficiency, & appropriate technology. Contact: Autonomous & Sustainable Housing, 9211 Scurfield Dr NW, Calgary, Alberta T3L 1V9, Canada • 403-239-1882 • Fax: 403-547-2671 jdo@acs.ucalgary.ca www.ucalgary.ca/~jdo/ecotecture.htm

The Institute for Bioregional Studies demonstrates & teaches ecologically-oriented, scientific, social & technological achievements. Info: IBS, 449 University Ave, Charlottetown, Prince Edward Island C1A 8K3, Canada • 902-892-9578

Vancouver Electric Vehicle Association, Call for meetings: 1402 Charlotte Rd., North Vancouver, BC V7J 1H2, Canada 604-987-6188 • Fax: 604-253-0644 rcameron@statpower.com

CHINA

Jun 11-15, 2000: Hydrogen 2000, Beijing, China. 13th world H2 conference. Info: WHEC2000/CICCST, Room 722 No 86 Xueyyan Nan Rd, Wei Gong Cun, Beijing 100081 China • (86-10) 62180145 Fax:(86-10) 62180142 zhenyj@public.bta.net.cn www.ciccst.org.cn/hydrogen

COLUMBIA

Oct 11, Expouniversidad 99—Energia, desarrollo y calidad de vida. Mechanical Engineering University of Antioquia, Medellin. Info: Marina Carvajal, carvaja@udea.edu.co

NICARAGUA

August 3-13, '99: Course on Solar Energy In Nicaragua (repeated Jan, 2000). Introduction to PV for developing countries: combination of lectures, field experience, and tourism. Taught in English by Richard Komp of Maine Solar Energy Society and Susan Kinne of FENIX & Nicaraguan Engineering Univ (see *HP61).* PV panel assembly and installation of lighting systems in a rural village. $750 (all expenses except air fare). Info: Barbara Atkinson • 215-942-0184 lightstream@igc.org

PORTUGAL

Nov 10–14, International Exhibition on Environmental Technology, Energy & Natural Gas. Info: Feir Internaciojnal De Lisboa 351-1-360-1500 • Fax 351-1-363-3893 expoambiente@aip.pt • www.emml.com

NATIONAL U.S.

American Hydrogen Association nat'l headquarters: 1739 W 7th Ave, Mesa, AZ 85202-1906 • 602-827-7915 Fax: 602-967-6601 • aha@getnet.com www.clean-air.org

American Wind Energy Association. Info about US wind energy industry, AWEA membership, small turbine use, & more. www.igc.org/awea

Reports on State Financial and Regulatory Incentives for RE. Order: North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695 • 919-515-3480 • Fax: 919-515-5778 www.ncsc.ncsu.edu/dsire.htm

Energy Efficiency and Renewable Energy Clearinghouse (EREC) offers: Insulation Basics (FS142), New Earth-Sheltered Houses (FS120), PV: Basic Design Principles & Components (FS231), Cooling Your Home Naturally (FS186), Automatic & Programmable Thermostats (FS215), & Small Wind Energy Systems for the Homeowner (FS135). Info: EREC, PO Box 3048, Merrifield, VA 22116 • 800-363-3732 TTY: 800-273-2957 • energyinfo@delphi.com www.eren.doe.gov

Oct 16, National Tour of Solar Homes. Info: ASES, 2400 Central Ave #G-1, Boulder, CO 80301 • 303-443-3130 • ases@ases.org www.ases.org/solar

Energy Efficiency and Renewable Energy Network (EREN), links to hundreds of gov't and private internet sites & offers "Ask an Energy Expert" online questions to specialists. www.eren.doe.gov 800-363-3732

Green Power web site: Discusses green power including deregulation, "green" electricity choices, technology, marketing, standards, environmental claims, & varying national & state policies. Links, articles & news. Global Environmental Options (GEO), & the Center for Renewable Energy & Sustainable Technology (CREST) www.green-power.com

Kids to the Country, an ongoing program to show at-risk urban children a country alternative. Info: PLENTY, 51 The Farm, Summertown, TN 38483 • 615-964-4391 ktc@thefarm.org

Tesla Engine Builders Association (TEBA): info & networking. One version is reported to consume 38 lbs of steam per HP/hr. Send SASE to TEBA, 5464 N Port Washington Rd Suite 293, Milwaukee, WI 53217 teba@execpc.com • www.execpc.com/~teba

Sandia's web site includes "Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices," "Working Safely with PV," & balance-of-system technical briefs, info on battery & inverter testing • www.sandia.gov/pv

Solar Energy & Systems, Internet college course. Fundamentals of small RE. Weekly assignments reviewing texts, videos, WWW pages, chat room, & email Q&A. Mojave Community College. $100 plus $10 registration. 800-678-3992 lizcaw@et.mohave.cc.az.us chacol@hal.mccnic.mohave.az.us

Federal Trade Commission free pamphlets: Buying An Energy-Smart Appliance, EnergyGuide to Major Home Appliances, & EnergyGuide to Home Heating and Cooling. Contact: EnergyGuide, FTC, Rm 130, 6th St & Pennsylvania Ave NW, Washington, DC 20580 • 202-326-2222 • TTY: 202-9326-2502 www.ftc.gov

The Interstate Renewable Energy Council, SEIA, & Sandia: handbook for government procurement officials and others on the specs and purchase of RE. US$15 ppd (make checks to ASES), Interstate RE Council Distr Center, c/o ASES, 2400 Central Ave Ste G-1, Boulder, CO 80301

Solar curriculum for upper elementary & intermediate grades—Free! Six week science curriculum or individual sessions. Over 30 classroom presentations and demos using free or low cost materials. Student tested, teacher approved. Florida Solar Energy Center, Susan Schleith • 407-638-1017 www.fsec.ucf.edu

ALABAMA

The Self-Reliance Institute of NE Alabama seeks others interested in RE, earth sheltered construction, & other self-reliant topics. Info: SINA, 6585 Co Rd 22, Centre, AL 35960 • cevans9@tds.com

ARIZONA

Tax credits for solar in Arizona. A technician certified by the AZ Department of Commerce must be on the job site. Info: ARI SEIA, 602-258-3422

CALIFORNIA

Campus Center for Appropriate Technology, Humboldt State University, Arcata. Ongoing workshops and presentations on alternative, renewable, and sustainable living. Contact:

CCAT, HSU, Arcata, CA 95521 • 707-826-3551 • ccat@axe.humboldt.edu www.humboldt.edu/~ccat

Aug 6-15, '99: 10-day Permaculture Design Workshop, Camptonville, Northern California. Led by permaculturists Dan and Cynthia Hemenway. Integrating human activity with the contour, soil, solar energy, and water flows of the site to provide water, food, shelter, energy, etc. Register for the full workshop or just the initial weekend. Enrollment is limited. Child care can be arranged with advance notice. Send SASE for a complete flyer. Scholarship applications may now be submitted—deadline: July 14. Scholarship & additional info: Birdsong Sundstrom, P.O. Box 125, Camptonville, CA 95922 • 530-287-3413 • birdsong@sccn.net. To arrange for advanced work or online course credit, or to book another workshop in your own region, contact: Elfin Permaculture, P.O. Box 52, Sparr, FL 32192-0052 USA • Permacltur@aol.com

Aug 20-22, Home Education Conference, Radisson Hotel, Sacramento, non-religious home-schooling conf. Info: Barbara David, PO Box 231324, Sacramento, CA 95823 916-391-4942 • CHEC95@aol.com www.HomeEdConference.com

Rising Sun Energy Center. Ongoing solar energy classes incl electricity, water heating, cooking, & kids day. Info: PO Box 2874, Santa Cruz, CA 95063 • 408-423-8749 sunrise@cruzio.com www.cruzio.com/~solar

Siemens Solar PV training: Basic PV Technology Self-Study Course, & Comprehensive Photovoltaic System Design Seminar. Contact: Siemens Solar Training Dept, 805-388-6568 • Fax: 805-388-6395 cvernon@solarpv.com • www.solarpv.com

Institute for Solar Living, Sustainable Living Workshop series through October '99. Beginning & advanced solar electric systems, passive solar, ecological design, sustainable waste water design, straw bale, cob & rammed earth construction, & more. Info: ISL, PO Box 836, Hopland, CA 95449 800-762-7325

NCSEA Sacramento Solar Speaker Series, SMUD Customer Service Center, second Monday of every month, 7 to 9 pm. Speaker info, call 916-44-SOLAR

COLORADO

Sept 5-6, Tenth Annual Crestone Energy Fair, Crestone Town Park, Crestone, CO. Dealers, vendors, musicians, and builders together for sunny fun in the park. Energy Council/Green Goods Raffle. Solar and alternative building. Tour homes using PV, wind, solar thermal, straw bale, earthships, adobe, and more. Info: Mountain Power Design, Boxholder, Crestone, CO 81131 719-256-4838

Solar Energy International, hands-on workshops: solar, wind, & water power. One & two week sessions: PV Design & Installation, Advanced PV, Wind Power, Micro-hydro, Solar Cooking, Environmental Building Technologies, Solar Home Design, & Straw Bale Construction. Experienced instructors & industry reps. For owner-builders, industry technicians, business owners, career seekers, & international development workers. $500/week. SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

National Wind Technology Center, Golden, CO. Assisting wind turbine designers & manufacturers with development & fine tuning. Info: 303-384-6900 • Fax: 303-384-6901

FLORIDA

August 23–25, Energy '99, Achieving Your Goals Conference, Orlando. For professionals interested in energy & water efficiency, & renewable energy. Contact: JoAnn Stirling 800-395-8574 Fax 407-638-1010 • joann@fsec.ucf.edu www.energy99.ee.doe.gov

GEORGIA

Nov 17-20, NAEVI '99, N American EV & Infrastructure Conference, Atlanta, GA. Info: EVAA, 601 California St #502, San Francisco, CA 94108 • 415-249-2960 Fax: 415-249-2699 • ev@evaa.org www.evaa.org

IOWA

Sept 23–26, Iowa All-Energy Expo. Sheraton Convention Center, Cedar Rapids, Iowa. Events, solar cars, electric cars, Cedar Rapids electric bus, Electrathon, demos. Workshops: PV, wind, active vs passive, political issues. Iowa Electrathon Race. Info: I-Renew, PO Box 466, North Liberty, Iowa 52317 • 319-338-3200 • irenew@irenew.org www.irenew.org

Iowa Renewable Energy Association (IREA) meets 2nd Sat every month at 9 AM, Prariewoods, Cedar Rapids. All welcome. Call for schedule change. I-Renew, PO Box 466, North Liberty, Iowa 52317 319-338-3200 • irenew@irenew.org www.irenew.org

KENTUCKY

Appalachia-Science in the Public Interest. Projects & demos in gardening, solar, sustainable forestry, & more. Info: ASPI, 50 Lair St., Mt Vernon, KY 40456 606-256-0077 • aspi@kih.net www.kih.net/aspi

MASSACHUSETTS

Greenfield Energy Park needs help preserving Greenfield's historic past, using today's energy & ideas, creating a sustainable future. Info: Greenfield Energy Park, NESEA, 50 Miles St, Greenfield, MA 01301 • 413-774-6051 • Fax: 413-774-6053

Sept-Dec, Sustainability Series, workshops and lectures. Info: NESEA, 50 Miles St, Greenfield, MA 01301 • 413-774-6051 Fax: 413-774-6053 • nhazard@nesea.org www.nesea.org

MICHIGAN

Tillers International, classes in draft animal power, small farming, blacksmithing, & woodworking. Catalog: Tillers Int'l, 5239 S 24th St., Kalamazoo, MI 49002 616-344-3233 • Fax: 616-344-3238 TillersInt@aol.com • www.wmich.edu/tillers

MONTANA

Sage Mountain Center: Life Skills Workshops. One day classes: Inexpensive earth-friendly home building, straw bale construction, log furniture, cordwood construction, natural & non-toxic interiors, & more. $55 incl literature. Info: SMC, 79 Sage Mountain Trail, Whitehall, MT • 406-494-9875

NEVADA

July 23-28, 2000: Year 2000 Conference: GlobeEx—the Global Energy Exposition & ENERGEX 2000, Las Vegas, Nevada, Riviera Hotel Convention Center. Marketing U.S. alternative energy technologies to emerging markets. Pre-event certification workshops in PV and finance, technical & plenary sessions, keynotes, social activities, & energy tours in Nevada & California. Presenters: U.S. Secretary of Energy, Bill Richardson; Christopher Flavin, WorldWatch Institute; Admiral Richard Truly, National Renewable Energy Laboratory; Kun Mo Chung, International Nuclear Energy Academy; & Tim Mackay, Commonwealth Department. Exhibition & paper submission info: Ms. Kathleen J. Moon, PGI Exhibitions, 8989 Rio San Diego Dr., Suite 160, San Diego, CA 92108 • 619-294-2999 x 140 kmoon@pgi.com

NEW MEXICO

Profit From The Sun workshop series, Moriarty, NM. Renewable energy, energy conservation, sustainable living, & energy independence. Contact: James or Marek at PSF, Inc, 505-281-1300 days; or James at 505-832-1575 eves & weekends proffit@flash.net

NORTH CAROLINA

How to get Your Solar-Powered Home: RE seminars through summer of 2000. Info: Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 • 336-376-9530 solarvil@netpath.net

OHIO

Solar/wind classes. Second Saturday of each month, 10 AM to 2 PM. Tech info, system design, NEC compliance, efficient appliances. See equipment in use. Max 10 students. Register in advance. $65/person $85/couple (spouse only). In spring: hands-on straw bale post & beam building. Solar Creations, 2189 SR 511 S., Perrysville, OH 44864 • 419-368-4252 www.bright.net/~solarcre

OREGON
August 16-19, '99: Photovoltaic Workshop, Lane Community College, Eugene, Oregon. PV theory & application, & hands-on instruction. The class will end with a local installation. Instructor: Greg Holder,owner of Alternative Means in Fall Creek, Oregon, & resident PV expert at Lane Community College. Info: Northwest Energy Education Institute at Lane Community College 800-967-9687 or (541) 744-3977 www.nweei.org

Aprovecho Research Center, non-profit educational institute on forty acres in the OR forest. Internship Sept 1 and six week winter internship in Baja, Mexico: Study and research appropriate tech applications, learn Spanish, teach grade school, & work fruit orchards & gardens. Info: Internship Coordinator, Aprovecho Research Center, 80574 Hazelton Rd., Cottage Grove, OR 97424 • 541-942-8198

Oct 2, Solar Energy Association of Oregon: 20th Anniversary Conference, World Trade Center, Portland. Keynote speakers Jeff Cook, Professor, Passive Solar Architect & Educator from AZ State Univ., & John Reynolds, Univ of Oregon, Building Energy Specialist. Speakers including Curtis Framel from the USDOE Million Solar Roof Program & Larry Sherwood from the Am. Solar Energy Society. Trade Show (open to the public), Building Projects & workshops, local solar energy specialists. Contact SEAO: 503-231-5662 • 205 SE Grand Ave, suite 202, Portland, Oregon 97214 www.oikos.com/seao

TEXAS
The El Paso Solar Energy Association bilingual web page. Info in Spanish on energy and energy saving. www.epsea.org www.epsea.org

WASHINGTON
Solar Energy International hands-on workshops in the San Juan Islands: Oct. 3, RE for the Northwest, $75. Oct 4-9, PV Design & Installation, $500. Oct 11-15, Microhydro Power, $500. SEI, POB 715, Carbondale, CO 81623 • 970-963-8855 Fax: 970-963-8866 • sei@solarenergy.org www.solarenergy.org. Or contact ianw@pacificrim.net for local information.

GreenFire Institute: workshops and info on straw bale construction. GreenFire, 1509 Queen Anne Ave #606, Seattle, WA 98109 206-284-7470 • Fax: 206-284-2816 wilbur@balewolf.com • www.balewolf.com

September 17–20, Water Harvesting, hands-on permaculture workshop, Orcas Island, WA. Contact: Bullock Workshops, c/o WE-Design, PO Box 45472, Seattle, WA 98145 or Michael Lockman, 206-567-5447 michaellockman@juno.com

WISCONSIN
Midwest Renewable Energy Association (MREA) Workshops. See ad. Call for cost, locations, instructors & further workshop descriptions. MREA Membership & participation: all are welcome. Significant others 1/2 price. Info: MREA, PO Box 249, Amherst, WI 54406 • 715-824-5166 Fax: 715-824-5399 • mreainfo@wi-net.com

the Wizard speaks…

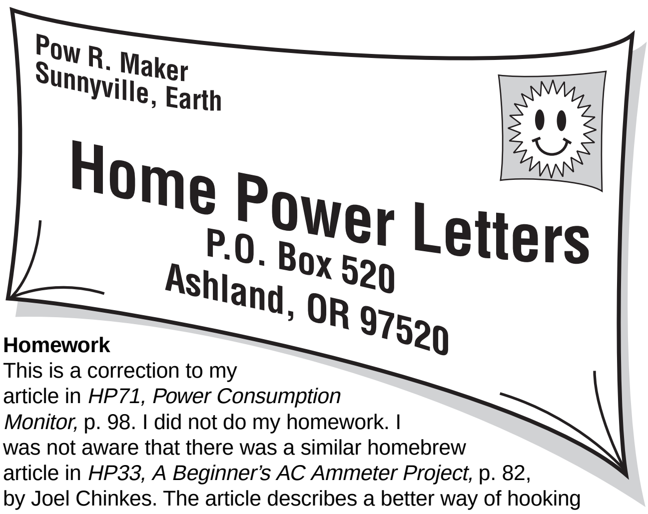
Resource Depletion

One of the possible threats to the ecological stability of the Earth is the depletion of resources from the environment. These resources are not limited to minerals and fossil fuels, but include the basic organic substances of life.

Almost all human activities tend to remove these resources from the biosphere. They wind up in manufactured things, in buildings, in garbage dumps, and as sewage that is dumped into the ocean. They also return to the environment as pollution of all kinds, including carbon dioxide from the burning of fossil fuels.

For similar reasons, fusion power is not an answer to the energy problem. In using water as a fuel, fusion will deplete hydrogen, an important organic constituent, from the biosphere. It will also increase the oxygen content of the atmosphere. There is no way to recover the hydrogen or to sequester the oxygen.

As resource use and population rise, a time may come when massive amounts of resources must be returned to the environment. This may be necessary to stave off ecological collapse. We can help to avoid this situation through such activities as composting and recycling. All activities which return resources to the environment or help to prevent further depletion should be encouraged.



Homework
This is a correction to my article in *HP71, Power Consumption Monitor,* p. 98. I did not do my homework. I was not aware that there was a similar homebrew article in *HP33, A Beginner's AC Ammeter Project,* p. 82, by Joel Chinkes. The article describes a better way of hooking up an ammeter to a modified outlet. Joel called me to let me know, and I feel sorry for not mentioning his work. Michal Vojtisek-Lom mivst5+@pitt.edu • 877-6-MICHAL

Guerrilla Glitch
Dear *Home Power,* I live in the northeast. The utility company just installed a new meter. This new meter allows the meter reader to get the reading without leaving his vehicle.

I have a 900 watt (soon to be 2.8 KW) array and my Trace 4024 in sell mode. I noticed the reading on my utility bill does not match the actual meter reading. I suspected that the remote device keeps ticking forward and does not allow for "net metering" even though the mechanical part of it does.

I took a closer look (though the glass case, of course) at the way this meter obtains and transmits its data. The utility installed a sensor that simply counts the black lines on the watt-hour wheel. This sensor does not care what direction the wheel spins, it just keeps on counting those little black lines—UP! It is a modification to the standard KWH meter. You can identify it by the black sensor that covers the WH wheel in the front and a circuit board below.

Solar Guerrillas may have a problem with this type of meter. I will have to make some decisions now—make a call to the utility or allow for some confusion and lose my energy savings when they pull the meter. I estimate they will be off by 640 KWH over the year when the balance of the Kyocera 120s are installed.

With the use of Guerrilla Solar and energy saving measures, my grid KWH usage has dropped from 72 KWH per day to 8 KWH. Not bad for a 2,800 square foot home and (currently) 900 watts of solar. Anonymous Solar Guerrilla

Yipes! I suspect that the power company will replace your meter if they ever try to reconcile their remote reading with the reading on the actual meter. The bottom line is that the power company is actually charging you for the solar electricity you put online. They should be paying you since you live in a net metering state. Contact your utility and tell them you want to net meter your system. It will save you a nice chunk of change.

Good work! Reducing energy consumption from 72 to 8 KWH is quite a feat! Richard Perez

Y2K Prescription
Dear *Home Power,* what a pleasure to read an article on Y2K/RE that is so filled with common sense.

We have been in the RE business here in northwestern Ontario (Canada) for six years. Our homes, office, and shop run on solar & wind, with backup generators (we are off-grid). Of course, our power consumption is small compared to average on-grid consumers.

Most of our business is for the summer cottage market as there are many lakes in the district where conventional power is not available. People are starting to catch on to the idea that you can have lights and a few other electrical conveniences at the cabin without the noise and fumes of a gas generator.

Living year round with RE is a whole different ball game—especially where winters are severe, daylight hours are short, and power consumption increases as a result. When people ask us about solar for Y2K for their conventional on-grid homes, we get some weird looks when we suggest that they: 1) install a good woodstove (that requires no electricity for fans, pumps, etc.); 2) dig a hole and build an outhouse; 3) purchase a good generator and be sure the wiring is installed properly. "But don't you sell solar panels?" is the usual response. "Yes, but…"

Your article sums up the rest of the story. In our opinion, too many dealers have sprung up and are trying to cash in on the Y2K scare. In reality, PV for this part of the world in January for conventional power users is unrealistic. Not so for the very wealthy dealers who try to make out, and likely may end up giving our industry a bad name.There are no quick fixes, as your article points out.

We have been supplying and installing RE systems for six years and intend to be doing so long after the Y2K bug (and whatever it brings with it) is squished and forgotten. Thank you for continuing to spread the good word. Power to ya! Jane Oldale, Frank's Alternate Energy, RR #3, Thunder Bay, ON Canada P7C 4V2 • sunwind@norlink.net www.sunwindwater.com

Fuel Cell Assumptions
While I enjoyed reading Joshua Tickell's *The Future of Transportation, HP70,* and concur with many of his conclusions and observations, I must take strong but respectful exception to his take on the role of transportation fuel cells. His statement, "fuel cell vehicles offer no relief from the shortage of fossil energy," is only, I feel, accurate given very stringent and unrealistic assumptions.

One such assumption: that hydrogen "would be produced from grid electricity." So? In the very same *HP* issue, the Guerilla Solar profiles show hope for an end to hydrocarbon dominated grid power. It will take time for this change to happen, certainly, but it will take just as long for the hydrogen hybrid vehicle to become affordable and widespread. If the grid changes its sources, hydrogen becomes renewable.

And what of those living off-grid? Walt Pyle's excellent homebrew hydrogen article in *HP69* gives us a glimpse of what folks could do in the future. Imagine powering long-range vehicles without sacrificing garden acreage to biodiesel crops. I can think of no other fuel that gives people that freedom.

It seems to me that much of Joshua's anti-FC bias concerns the funding motives behind the current research frenzy. Right now, I agree: that cash is "a job creation program for desperate automakers," as he observes. But I say, so be it. We as hopeful consumers need research dollars to perfect the technologies, and the perceived market to mass produce the gadgetry and bring it to affordable levels. Personally I don't care where those R&D bucks originate. This research is good, period.

Also, just because this research focuses on the mobile FC for transportation, nothing prevents this focus from yielding immensely valuable applications yet unimagined. For example, rumor has it that extensive R&D is going into fuel cells powered not by hydrocarbons, but by ammonia (NH3). Think of all the urine that could be filtered to create power... Sincerely, Jim Dempsey, Seattle, WA Jim@Dempsey.net

Jim, regardless of how much research money is spent on hydrogen fuel cells, it takes more energy to make, store, and convert hydrogen than hydrogen contains. No matter how you slice it, creating hydrogen with electricity and then converting the hydrogen back to electricity will consume more than 75 percent of the input energy. This means for every 1 unit of electrical energy you put in, you only get 0.25 units out. In terms of cost per kilowatt-hour, every $1 spent on making hydrogen will yield $0.25 in electricity.

Vegetable oil-fueled diesel cars and solar-powered electric cars are currently the two most efficient means of converting solar energy into long range transport (excluding walking, cycling, and horseback riding). Biodiesel contains at least 2.5 times the energy needed to fertilize, grow, harvest, process, and transport the fuel. This means one gallon of biodiesel contains 150 percent more energy than was used to make it. Diesel cars that get over 50 miles per gallon are on the market today. Over 3 billion gallons of used cooking oil are produced in the U.S. each year. There are over 50 million acres of cropland left fallow in the U.S. each year. In addition, the Department of Energy estimates that over 4 quadrillion BTUs of biodiesel (enough to meet the fuel needs of the U.S.) could be grown from algae on less than half a million acres of desert.

Our planet is quickly depleting its petroleum energy reserves. We should use the upcoming petroleum shortage as an incentive to institute efficient, inexpensive forms of solar-powered transportation. I refuse to wait around while flashy automobile ads tell me what a George Jetson fuel cell car might look like ten or twenty years from now. I want clean, reliable, inexpensive, decentralized, and accessible transportation today. Joshua Tickell • biodiesel@best.com

Induction Generator Kudos

I wish to commend Bill Haveland for the excellent article he wrote on induction generation in *HP71.* I have also done research and experimentation in this area (see *HP3).* There are a few things upon which I would like to comment.

My experience has been that higher efficiency is attainable using a three phase system, rather than the single phase system Mr. Haveland used. My systems use three wire output, three capacitors, and three phase transformation and rectification. Higher efficiency is attainable using a three phase system because it is balanced and the capacity will be greater because all three phases are being used in the generator. This may increase complexity somewhat, but it's more user friendly as the capacitors are now all the same size.

The primary demon contributing to low efficiency is the power factor (PF). This refers to the phenomenon in AC circuits in which voltage and current do not necessarily stay in sync. I have built induction systems where zero power made it to the batteries. Even though power was being generated, it would not make it through the transformers I used. This remarkable achievement I attribute to poor PF. This is a black art we are dealing with. Each motor and transformer combination acts differently. Single phase systems have inherently poor PF as the charging current can only come from the highest voltage part of the waveform. This is why a genset can only manage to put a fraction of its output through an inverter and into batteries.

There are techniques, other than using transformers, to get the power into batteries. Electronic power conditioning is a possibility. I have used Todd chargers and LCBs for this purpose. While efficiency is usually high, reliability often is not and seems to be related to the distance the customer is located from me. These devices are usually smaller and lighter than transformers. Some are tuneable which means that the system output can be optimized by adjusting a knob instead of changing capacitor size or using transformers with multiple taps. Custom built transformers can help here as they can be specified for the often odd frequencies and voltages.

I have some concerns over how the efficiency figures are arrived at in the article. I see in the first system (Bosque Del Cabo Lodge) that the rectifier efficiency is shown as 98.9 percent charging 12 V batteries. Even if center tapped transformers are used, which would create only one diode drop, this would produce about a 0.8 V drop in the standard diodes that he is using. In a 12 V system that is operating at 14 V, this would be 0.8 ÷ 14 = 5.7 percent or a rectification efficiency of about 94.3 percent. It is not possible to achieve the figure stated in the article. This site also operates at 66 Hz or 4,000 rpm when the optimum speed for a head of 190 feet is 2,900 rpm and 48 Hz. The question posed in the article as to why one system operates at "abnormally high efficiency" might better be asked: why are the others so low?

Careful system design is everything. Although induction generation is an intriguing possibility, it will take more work and research to allow it to reach its potential. I enjoyed Mr. Haveland's article and I look forward to hearing from others regarding this very interesting subject. Paul Cunningham, CEO, Energy Systems & Design • 506-433-3153 Fax: 506-433-6151 • hydropow@nbnet.nb.ca www.microhydropower.com

Independently Dependent

Dear *HP,* Being new to off-grid living, I have some concerns with renewable energy products. If it is the desire or necessity for one to be free of power companies, then independence is important. *Home Power* readers seem to be a self-supporting group of people—building, wiring, measuring, computing, and designing systems to provide energy for our everyday activities, whether cooking, washing, driving, lighting, or constructing solar installations for power. My concern is how can we be such an independent group of people and allow ourselves to be so dependent on the manufacturers of the equipment we use to accomplish this.

I have contacted most of the suppliers of inverter equipment and am finding they will not support purchasing or supplying documentation for the repair of their equipment—schematics, board layouts, circuit descriptions, repair parts, etc.

I realize not all want to, can, or should repair equipment, but for those that can do repair, that door is effectively shut as far as the manufacturers are concerned. One company source was candid and said, "We do not want you to repair your own equipment—we want to make the money." He went on to say they receive several calls per week from customers requesting schematics, etc. I find this to be a very interesting position since we can obtain documentation to repair a TV, microwave, VCR, CD player, DVD player, refrigerator, car, house wiring, but not solar equipment.

Even if I decide to repair the equipment and am not successful, I still have several choices. I can send the equipment to the manufacturer for repair at my expense, buy new equipment, do without, or design my own. Even if the equipment were under warranty, the manufacturer has the right to void it and charge me whatever they want for repairing the unit if I ruin it. Otherwise, I could purchase a new one. The point is that it should be my choice.

At the present time, I am required to reverse engineer the equipment and draw schematics, which is very time consuming. Safety, of course, is always a concern, but is this equipment more demanding than cars, brakes, steering, etc? I am interested in your position on this as you can bring a lot of pressure to the manufacturers. I do not believe anyone wants this for free, I am certainty willing to pay reasonable costs for documentation (my Expedition auto service manuals cost $156). Any help you can provide for the long-term should help many individuals.

As a subnote, I am a "ham," WA7PNO (40+ years), and hold a first class radio license. I'm a Pentium III design program manager at Intel, a registered professional engineer, and have designed many solar controllers (using 8751 to 486s) for my RV over the years. I have all

of the necessary equipment to perform the repairs and the frequent upgrades I find necessary. John Young, Higley, AZ john.e.young@intel.com

Hello John. Thanks for your letter. It echoes exactly how I feel. Inverters, controllers, and instruments should come with access to a full line schematic, printed circuit board layouts, and technical info on how they work and can be repaired. You are correct—this data is furnished, or can be obtained, with just about all other "appliances."

I, too, am an FCC-licensed techie, and know how to run a DMM and a soldering iron. I too would like to be able to fix what goes wrong here, but can't because I don't have the "road map." Richard Perez

Pedal Power

If I wanted to create a short-duration, simple, free, but effective source of AC electricity, couldn't I take an old electric motor which was made to work on AC, attach the moving part of the motor to a stationary bike, attach the leads to my home's AC network, and start pedaling? If so, I'm thinking this could produce enough juice to run my oil-burning (but electric ignition) boiler for short periods of time as a sort of winter-time-power-outage/Y2K stopgap. Am I crazy, or just electrically ignorant? Marc Bobrow, Windsor, CT marc.a.bobrow@us.pwcglobal.com

Hello Marc. Yours is a frequently asked question, and your heart is in the right place. However, there are some technical problems with this idea.

The electric part of that oil burner could easily consume over 400 watts with pumps and blowers running. An Olympic cyclist can produce about 200 watts for a few seconds and about 75 watts for over an hour or so. Chances are you can't pedal hard enough or long enough to directly power that oil furnace.

Using an AC motor will work, but it will have to be spun at its rated rpm to produce 60 Hz electricity. Chances are that means spinning the motor at 1,800 rpm, which means a gear-up drivetrain from the bike. You'll have a lot of losses in this system, with much energy wasted in power transfer.

Consider putting a small (about 100 watt) DC permanent magnet motor (which is also a DC alternator) on the bike. Then pedal when you can and make about 75 watts while you are pedaling. Store this energy in a battery. Use an inverter to power the oil furnace and other small 120 VAC appliances. Richard Perez

Marc, a good article on the basics of pedal power is Pedal Power *by John W. Hill, in* HP23, *p. 48. Another good one is* Pushing Pedals, *by David Haaren in* HP31. HP56 *features a pedal power homebrew article,* Electro-Biking, *by Bill Gerosa. You can search our* Solar2 & Solar3 *CD-ROMs for these articles and more. Joy Anderson*

Baboon Problems

Dear *Home Power,* I get so much pleasure out of your magazine—thank you so much for doing what you do. It seems so few pleasures in life are guilt-free or good for one's health. I applaud the great work you've done over the years and hope you continue. Just got the *Solar3* CD-ROM—what an outstanding resource. The design is excellent.

I just moved from western Uganda to the forest in equatorial Tanzania where I do chimpanzee research and conservation. I've lived with solar for four years now. I use it for lights, radio, PowerBook, and battery charging. My new site has a stream, and I've just ordered a Lil' Otto—can't wait to try it out. My system is an eclectic mix of high-tech and ultra-low tech. In rural Africa, it can be a real challenge to design and maintain anything with locally available or handmade parts. I've been using six of AEE's 10 watt single crystal "clone" panels mounted on a wood frame with a Morningstar Prostar 20 to charge a 100 AH truck battery. I chose these panels because of their compact size and ultra light weight—each like a clipboard—easy to pack in a bag and haul to Africa.

At my old place in western Uganda (about one mile south of the equator), I built a low (and I mean low) tech tracker made out of machete-made timber, a bungee (to return to east) and fishing line. From inside the house, you pulled on the line while looking at the ammeter! I built a solar hot water heater for about 30 bucks with a 10 gallon jerry can insulated with discarded bubblewrap and 30 meters of black plastic pipe as a collector—it worked great.

Here in Tanzania (about 29°E, 5°S), I'm in a forested valley. The resident baboons are my current problem. They like to sit on the array, which is currently mounted in a tree. I might try some heavy duty thorns, but in lieu of that, I envision some sort of efficient homebrew electric fence-type live wire. Maybe it needs an infrared sensor so it turns on in the presence of baboon? Any ideas? Bird droppings and leaves are one thing, but needless to say it is quite unpleasant to scale a tree and risk running into deadly green mambas, boomslangs, and cobras just so you can clean baboon crap off your solar panels.

I seem to always find myself having esoteric engineering problems. Deep cycle batteries are incredibly expensive here, of questionable quality (or not available in most of Africa), so we make do with truck batteries. I figure the PWM from Prostar helps this, and I try to cycle as shallow as possible and immediately recharge. Got two years+ out of my last Ugandan-made battery.

I use an "Eco-charger" bought from Real Goods to recharge NiCds and alkalines for flashlight use. I've had great luck with this device, and would be interested to hear your opinion of it. It seems to charge my NiCd's quite well (lately I've been using the 1,000 mAH Radio Shack Hi-Cap AA's for flashlight use around camp). For forest use, I use alkalines (about 2 hours per day) which are then recharged in the Eco-charger. I generally frown on non-rechargable batteries, but considering our snake situation (not to mention the leopards), the extra 1/2 volt gives a slightly brighter light. Also, NiCds have that "sudden death" fading situation. We're running up and down valleys and cliffs and slithering through thick vines along bushpig trails following very fast chimpanzees for 12–14 hours a day with no food or water. Carrying an extra set of NiCds is not desirable in this circumstance. (We do get to eat some of the chimp foods which are actually quite good, but only when they're not looking!) It's hard to know how much this charger extends the lives of alkalines, as you recharge them as soon as possible after each use, but I think the company's claim of 8–12 times is valid. I'm about to convert the entire research staff over to this system, and will let you know of the results. It seems to me this might be a good product for mainstream America to be using—those who are too lazy to use NiCds (shame on them!) can simply pop them in and extend their battery's life considerably.

Another product of which I'm a huge fan is the Jade Mountain LED lamp. This is the 9 white-LED lamp made for them by LEDtronics. These babies draw around 60 mA or so (essentially nothing), and are just terrific. I cannot wait to see the great LED stuff that will come out in the next few years. I was testing a Holly Solar LED flashlight which I liked (alas—it was stolen). It had one LED powered by three AA cells, and I was thinking the 3 LED flashlight they make would be even better. Maybe not for anti-snake duty, but certainly in camp use it should extend battery life exponentially. I'm also in the process of an experiment with some homebrew LED lamps which came out of *Home Power* (LEDs from Hosfelt Electronics). A great white LED Web resource by the way is Don Klipstein (www.misty.com/~don/led.html).

In Uganda, the government estimates that the average household buys 100 liters of kerosene each year for light. With LEDs (the Jade Mountain small panel system comes to mind) one would think that this could be greatly reduced. I've often thought than an ultra simple portable task light with 3 LEDs or so, which could be powered from a

few cells and sold for about five dollars, would be a great product for Africa. Certainly LED replacement lamps for flashlights could be marketed here right now. NiCds are basically nonexistent in Uganda and Tanzania. People generally use horrible Chinese made (Matsushita licensed) cells which have a short life and are then discarded.

My partner Karen and I have often mused about starting a solar NGO to address some of these issues. I'm sure SEI has thought about these ideas quite a bit. I've often talked with a locally owned business in Kampala, Solar Energy for Africa, giving them new catalogs, and talking with them about marketing, new technologies, and some other product ideas. The solar market here is quite small, due to the high cost. Also, one needs to think about car batteries being used in the system, and factoring in yearly replacement costs. I would estimate that 90 percent of solar systems use car batteries. When you consider that three or four car batteries cost the same as one deep cycle, the cost works out very closely.

Needless to say, there is so much sun on the equator, not to mention year-round 12 hour days—no winter doldrums here. I can't help but envision Wattsun trackers with 90 watt BP panels everywhere. All power in Uganda is from a hydro dam on the Nile at Lake Victoria. As in many parts of the world, power cuts are a daily fact of life. I cannot help but think that if Uganda switched to compact fluorescents, "loading-shedding" (as they call it) would end overnight. We need to get the Chinese making cheap bulbs for the developing world.

Thanks again for the great work you do. If I can ever be of help, please let me know. John MacLachlan, The Jane Goodall Institute for Wildlife Research, Education, and Conservation, Gombe Stream Research Center, Gombe Stream National Park, Kigoma, Tanzania

John, thank you for your fascinating and entertaining letter. We're glad to hear about RE technology at work in the wilds of Africa. Would you consider writing up some of your systems for HP? *I bet our readers would love to see the photos and hear more about what you're doing.*

Though it's fun to dream of combining modern dairy technology with PV to make a baboon manure removal system, I think your idea of an electric fence wire sounds more practical. We've used electric fence here to keep raccoons out of our orchard and cows in the pasture. It's an easy load for PV to handle for most of the year, and the motion sensing switch is not necessary. The Parmak units use a small 6 or 12 volt module, not unlike the small panels you get from AEE. See HP21 *for an article Richard wrote years ago on a homebrew fence charger. We've been pleased with an electric fencing product called Electrobraid (www.electrobraid.com), which is a nylon rope with copper wires woven into it. Perhaps the company could send you a sample for testing on baboons... Ian Woofenden*

Fireplace Gizmo Found
Hi Richard, the latest *HP* arrived today, with lots of good stuff. Back in the *Letters* section, one reader asked about fireplace heat extractors. We had one about 20 to 25 years ago, back in the mid-70s, during the height of the energy crisis. I believe we got it at Sears. A quiet blower on the side pushed air through the grate, with the heated air coming straight out the front. We also bought a "fireplace doorscreen" from them, sized about two inches too short. This nicely complemented the approximately 2 inch high exhaust grill on which it perched. Lots of high temp cement later, it all worked. And the furnace stopped kicking in when we burned wood on winter nights.

I doubt that Sears still sells such a toy, but ya never know. And I'm sorry to say that I've completely forgotten the brand name of the blower/grate. Hmm…maybe a quick websurf would answer all... Hey, there's 69 hits using Alta Vista Advanced Query. The search term was "blower," and the boolean phrase was "fireplace and grate and blower." The first one that looked good is www.tfweb.com/fire/cozy.html, though they want $395 for a unit. Yipes! At least there's a line drawing, and it looks pretty close to what we used.

There may be other cheaper units out there. And I suppose that somebody who knew how to weld could whip one up and stick a blower on one end. Best, Jim Tolson • JTolson777@aol.com

Efficient Fans
Richard: A couple of months ago I wrote to *Home Power* for some advice on efficient fans with which to keep cool. Just wanted to give you an update. I found a pair of new-in-the-box Comair Rotron "Major" series fans at a surplus store for $10 each. Digikey lists these fans as model MR2B3. 115 VAC, 30 watts, and $56 new. Each fan will move 200 CFM. The only drawback is that they are noisy. So what I did is wire them in series. They still move a lot of air but they are now whisper quiet, and still draw only 30 watts.

I mounted the fans in a small frame that will fit in a window, also serving as a stand-alone unit that can be moved from room to room. Similar to "task lighting," the fans provide "task cooling." And just in time—we hit 100 degrees for the first time yesterday.

I think readers should be cautioned that these fans operate at very high speeds (even when running at half voltage) and are capable of doing severe damage to fingers. Some type of screening should be used as a finger guard to help prevent injuries. The fans are a bit spendy but I thought your readers may have some interest in a solution like this. Cheers, Chuck Penson • wa7zze@juno.com

Overpriced LED Lights
LED lights are overpriced! Who needs this kind of efficiency with an estimated payback of over 20 years? LED lights are the rage, but retailers could care less. How do you try to sell a $100 flashlight and justify its lifetime of energy savings? This kind of efficiency is enough to put the lighting business out of business. Don Hall drhall@iglou.com

Hi Don. Good LED flashlights can be had for $35 and under. This price has been going down quickly, as the price of high-quality LEDs drops. LEDs are getting cheaper as their demand for industrial applications increase. At the same time, their color spectrum is improving. Admittedly, common incandescent flashlights are cheaper (for now), but payback is not the only issue, either. Length of battery life for flashlights has long been a concern. With LED flashlights, fewer throw-away batteries are tossed, and there is less need to recharge the rechargeables. Personally, I like them and will soon be buying one for myself to keep in my vehicle and on my belt. My other flashlight is a 14.4 volt Makita—now that's *a flashlight! Michael Welch*

Evacuated Tubes
Hello everybody at *HP*, I'm a recent subscriber. I've only received one issue so far, but the *Solar 2* & *Solar3* CD-ROMs prove to me that I'm not going to be disappointed! Fantastic production!

I read an interesting article in a UK-based construction magazine today. Basically it was about solar power in general and discussed the future of government grants for such projects on an industrial basis (BIG projects). One topic that was briefly touched on was "Evacuated Heat Pipe Solar Collectors," a technology developed by NASA. These apparently consist of a 1 metre long glass tube which houses a strip of material in a vacuum which chemically reacts with light at all wavelengths, so it works even in the absence of direct sunshine! In the building where these are employed, which looks like a fairly large 5 bedroom house, they produce 40 gallons of piping hot water each and every day.

These things obviously exist already because they've been installed on the house in the magazine article, which was the centerpiece for a BBC TV programme called "Dream House." Sadly, I didn't catch the programme as I work in Saudi Arabia and rarely get back to the UK. I'm at the design stage for a totally off-grid house on a little (365 acre) island called Rakino in the bay of Auckland in New Zealand, so all my

vacation time gets spent in places other than the UK (too bloody cold and wet!).

To cut to the chase, have you ever heard of these evacuated tube creatures and what's the lowdown on them, price and availability-wise? Look forward to your reply, keep up the great work on the mag, and best regards. Buz Burridge • buzzard@prime.net.sa

Hello Buz, thanks for the kind words on the CD-ROMs. The evacuated heat pipe technology is not new and you've already found Thermomax who is probably the leading manufacturer. We have had a 20 tube Thermomax array here for over a year now. We have it mounted side-by-side with a conventional flat plate collector which has 25% more surface area. The Thermomax consistently outperforms the flat plate collector, especially in the winter when temperatures are low and the wind is blowing. Cost is somewhat higher than conventional flat plate thermal collectors, but not radically so.

We bought the Thermomax collector from our local solar domestic hot water contractor. They install a lot of them here in Oregon. The tubes are about 2 meters long and 10 cm in diameter. We have them roof-mounted, facing south at a 45 degree angle.

The Thermomax should work well in New Zealand, but it's probably not worth the expense in Saudi Arabia. They are most effective in locations with low wintertime ambient temperatures. Richard Perez

Generating Interest

Have enjoyed *Home Power* for a long time and learned much. Now it's time to put it to use.

We live just south of St. Louis, Missouri, in a rural area. Our home sits on top of a ridge with trees all around. Although we've never been without power for more than a few hours (due to a tornado), I am concerned since we have an almost entirely electric home. No utility services are available but electric (or propane, to which we are converting our space heat and water heater). Our water supply comes from a well approximately 550 feet deep which supplies three other families. It uses a 2 hp pump with 220 volt electric motor. It seems to draw no more than about 12 amps per leg but the fuses are 20 amps. I want backup power so I'm looking at a generator. I think I need one at least 5,500 watts and wonder if diesel would be best, even though it's more expensive. I would like your thoughts.

I've seen the ads recently for the Hanzi diesels. They are so much cheaper. Have you experience or reports on them? An article comparing different diesels would be helpful to many of us. Thanks much, Rich George RiGeorge@aol.com

Hello Rich. Let's just look at the pump first. Even though the pump consumes around 12 amps per leg, its starting surge is probably three times that. Measure this with an instrument such as the Fluke 87 digital multimeter (DMM), which can measure and record the amount of starting surge. Generators have no surge capability—max watts is max watts. Just for the pump, you should be looking in the 8,000 to 10,000 watt range.

Moving the space and water heating to propane is a great idea, its cheaper and more effective. Get a big yard bomb—our propane tank here is 500 gallons and we fill it only once a year. Consider also moving the cookstove over to propane. If you switch all the thermal applications from electricity to propane, wood, or solar, then the rest of your home's loads are relatively small compared to the pump you mentioned.

The degree of quality you need in a generator depends on how you use it. The less expensive imported models will not have the longevity of the domestic Kohlers and Onans. In a strictly backup application (like when the power's out for a day or two), you wouldn't put much more than 100 hours per year on the generator. With care, even the cheapest generator will run at least 1,000 hours. In backup service, that's a total of ten years. By that time the generator will be obsolete, and the entire energy scene will have changed.

The Hanzi diesels are well made. In China, they power whole villages and run 24 hours a day. I really don't have enough hard information to write that generator article. We would have to install at least half a dozen of them and run them for a year or two to get real data. What I do have is hearsay testimony from many generator users. They write in here and share their experiences.

If you are strictly interested in short-term backup electricity (outage of an hour or two), then a battery and inverter combo costs only marginally more than a generator. For long term backup (power outages of weeks or months), the battery and inverter can greatly extend the life of the generator and reduce fuel costs. And once you have a battery/inverter combo, you can also add RE sources such as PV or wind.

In any case, please have your generator installed and wired to the appropriate loads by a professional electrician—someone who really knows how to do the installation. If the generator is not properly interfaced with your loads, then the grid can backfeed the generator (the generator will go down in flames, literally) or your generator can try to energize the entire grid when it's down. Richard Perez

World Sustainable Energy Fair vs MREF

A couple of years ago you reported that there were about 100,000 households relying on solar power for electricity and other power, mostly in the United States. This means that there are at least that many people with experience of using solar and other renewable energies for everyday use. If the climate of public policy ever changes, these people will be of use in teaching others how to do it.

So far it must be doubted whether the world's opinion formers and decision-makers have really grasped that we have serious problems with energy use and climate change. *Home Power* represents those who believe we don't have to wait for the big men to make their decisions but should go ahead without them.

The World Sustainable Energy Fair in Amsterdam (25–27 May 1999) was a contrast to such shows as the MidWest Renewable Energy Fair in Wisconsin. The American shows tend to concentrate on equipment for people doing it themselves, and are attended for the most part by people intending to do just that. It takes place outdoors and the equipment can be seen in action.

The energy fair in Amsterdam concentrated on government and big business and showed equipment inside a conventional conference and exhibition centre. The European Commission was represented with its ponderous policy documents.

Which of the two approaches is more effective? In Europe, governments seem to be taking serious steps towards promoting renewable energy, whereas in the U.S. governments are still inhibited by Big Business which seems to be unconvinced of the need to change. On the other hand, there seem to be many more individual Americans working with solar power on their own and rather few Europeans. Perhaps Americans need to do more to convince their governments, and Europeans need to do more work themselves.

I would guess that when the decision is made by the world's real decision makers (not necessarily those in the public eye), the changeover to a solar economy could take place astonishingly fast—perhaps in a single decade. So far, for all the talk about change, I don't think the world's leaders are yet serious.

Now, what would cause them to decide? Perhaps a hurricane in a place that has never seen one before, blowing in the windows of the White House, or a Wall Street bank? E.G. Matthews, Wimborne Energy Consultancy, 20 Brookside Road, Wimborne, Dorset BH21 2BL • Phone: 01202 885388 • wimtalk@compuserve.com

Electronic Subscriptions
Richard—first of all, great magazine!! I'm a new reader but am thoroughly impressed with the level of technical info and the overall commitment to renewables.

My question/comment is to inquire why you're not offering an electronic edition (Acrobat format) subscription option. It looks like you have sufficient internet infrastructure in place to make it work. Personally, I'm planning on ordering the CDs rather than hardcopy back issues and would love the opportunity to bypass the printed version altogether. I guess as long as you post the complete current version, I can always just download that and burn them to CD myself, but I would like the opportunity to financially support *Home Power.*

By the way, any idea of when the CD with the most recent (*HP61* and later) issues will be published? Thanks and Regards, Tom Ferguson ferguson_tom@yahoo.com

Hello Tom, we've considered Acrobat-based electronic edition subs, but the cost overhead of collecting the money and keeping track of all the subs is too high. So we give the current issue away for free in that format. If you want to support Home Power, *please adopt your local public library (see the ad in this issue).*

Solar 4 *(containing* HP61 *through* HP70, *battery & inverter lectures, video clips, and lots of other stuff) went on sale 21 June. Thanks for your kind words. We are pleased to be of use. Richard Perez*

Pulse Charging
Hello Richard, I have been looking for information on pulse charging. Is it as good as commercial suppliers say? Can a system be homemade or is it too complicated?

Even I could build the controller from the article from *HP70* as posted on your Web site. Very good! Very complete! Thanks for a good site. Richard Entenmann • entenmann@email.msn.com

Hello Richard. Yes, pulse charging is the way to go. Sandia Nat'l Labs has confirmed it with scientific testing. The only type of PV regulator to consider is a PWM type. Also the electronic desulfators work well. Pulse type units are more complicated than most charge controllers, but can be homebrewed. Sorry, no schematic for this yet. Thank you and I'm glad you liked the info and found it useful. Richard Perez

More on Cooling with Ground and Water
Richard, In *HP69,* Chris Snyder asks for information about soil cooling. Your answer and comment about being an electrical geek and asking readers for info is right on.

Enclosed is a newspaper article (*Northern Virginia Daily,* July 23, 1998) on the ground water cooling system we are installing. As the article states, on this site we have a virtually unlimited supply of cold water, however the same basic rules of physics apply, and one of our former employees cooled his 2,300 square foot home with a derivation of this system using a heat exchanger in his drilled well.

Ground cooling is not new technology. We were involved with a church renovation some years ago, and discovered a grating behind the pulpit, connected to a gazebo some distance away by a rock lined small tunnel. All this had been covered years ago by renovations, and of course the tunnel entrance was blocked with debris. A bit of clearing the entrance, and Voila! the whole picture comes into focus. The layout of the church: a raised pulpit at the rear of the building and a bell tower at the vestibule in the front, and we have exactly what your reader is looking for. Cool air flows from the gazebo, through the tunnel where it approaches the earth temperature, flows up through the grate behind the pulpit, over the edge of the pulpit stage, across the auditorium floor, and out the bell tower.

Unfortunately, a long tube is not as efficient as a manifold of tubes, since the temperature of the air decreases as it travels the length of the tube, and rate of heat transfer decreases as the differences between the air and the ground decreases. The trick is to get the airflow so that the exit air is within 2–3 degrees of the ground temperature, and the excess water (humidity) is condensed out and collected. There are tables of heat transfer in abundance. However, given the vagaries of heat transfer and differences in installation, my suggestion is to make one grid, try it, and if more is needed, install another grid in parallel.

A little known fact about air conditioning is that the exit air from an air conditioner is very nearly 100 percent humidity, and only when mixed with room air and increasing the temperature to 70°F or so does the humidity drop. The humidity is important; if the dew point is about 60°F or below, we are comfortable at dry bulb temperatures of as much as 80°F. A ground cooling system will need about two or three times the flow of an air conditioner to be comfortable because it will be difficult to get the air below about 60°F in any area where air conditioning is needed.

Our system uses a recycled pair of freon heat exchangers with the flow path altered to give four progressive passes for the water so that the air flows counter to the water flow, which will get the air temps to within 2–3°F of the water temperature. We are installing the units in the attic, pulling the warm air from a plenum in the top hallway, and directing the cool air through the 12 chimneys to the rooms (a requirement because all the walls, interior, and exterior are solid masonry).

The water exits the coils only a couple of degrees cooler than the incoming air. We use the water for lawn sprinkling because the law frowns on putting "used" water back into the stream(?). Pat and Susan Goodman, Atlas Energy, 534 Redbud Rd, Winchester VA, 212603 • pat-goodman@telepad.com

Charge Controller Comments
I am starting to convert from the grid to energy independence. My starting point is solar electric. I have batteries, box, and ventilation; four 110 watt solar panels; and a 1.1 KW Exeltech inverter. I'm still missing the distribution box, the heavy DR3624 (for the well pump), charge controller, breakers, and lots of other small things, but I wanted to test out what I already had and needed a charge controller.

I found yours and built it (Thanks!). Had to do a bunch of substituting (local Radio Shack and my junk box were my only source of parts). I used a 7812 for the 7815 (24 V system), 10 K potentiometers for the 20 K versions, and a different power MOSFET. The voltage sensing part worked fine, but I couldn't get the MOSFET switch to work (or get a big enough heat sink on it for the 12 amps from the array) so I substituted a relay. I had to heatsink that 7812 to handle the 4 watt draw of the relay, but it's only on when the batteries are fully charged.

So far, it works great! Thanks again! But there's more—the addition of the relay also lets me add a float charge mode (the bulk charge mode is the one that you provide). I'm adding an LM317 adjustable 3-terminal regulator to the charge path and setting it so that it's enabled when the battery is not "charging." The battery is on the center pole of the double-throw relay. When the battery falls below 25.4 V (my "on" setting), the relay drops out and the arrays are connected to the battery directly. When it gets above 28.8 V (my "off" setting), the relay's enabled and connects the batteries to the 26.8 V current-limited path (limited to 1.5 amps by the LM317)—also fed by the array is the float portion! David Kunz • davek@clark.net

Ozonal Notes

Richard Perez

Kathleen Retires!

After over ten years of working with *Home Power,* Kathleen Jarschke-Schultze is retiring. Don't worry readers, she will still be writing her regular *Home & Heart* columns, but she will no longer be part of our orders & sales crew. We all wish Kathleen the best of luck in her retirement and envy the free time she will have. Thanks, Kathleen, for the decade of hard and wonderful work you put into the RE industry and into *Home Power.*

Oregon's Net Metering Bill

It looks like Oregon may be the first state in the nation to pass a net metering bill that is not a net metering bill. After our success at getting our bill unanimously passed by Oregon's House, we ran into trouble in the Senate. Utilities stalled the bill for weeks in the Senate Public Affairs Committee and forced a number of compromises. We no longer get net metering, but now the utility can pay us only avoided generating cost (just like the existing, decades old, Federal PURPA law).

While the Oregon bill still does streamline the utility intertie process and forbid huge insurance requirements, it's been compromised to the point where all of us at *Home Power* are very disappointed. After a year of hard work in the political trenches, it's obvious where the political power really resides—with the utilities, not with the people. I predict that Oregon is going to become the number one Guerrilla Solar state in the USA.

ASES 99

I journeyed to Portland, Maine on June 12-17th to attend the 1999 American Solar Energy Society's annual conference. It was wonderful to meet and talk with some of the over seven hundred academic and industry folks who create and make the products we use daily in our RE systems. I was enlightened by the keynote address of Ross Gelbspan, author of *The Heat Is On,* regarding the facts of global warming. With utilities spending millions of dollars on ad campaigns to convince us that global warming is not happening, it was good and frightening to hear the truth.

We've got to stop pumping so much carbon into our atmosphere and we've got to stop it very quickly. According to Gelbspan, we need to cut our carbon emissions by 60 percent if we are to avoid global disaster. Get a copy of Ross' book and read it. Then put up some PVs and use them.

Guerrilla solar was a hot topic of discussion at ASES 99. I got a lot of "finger wagging" regarding *Home Power's* reports on guerrilla solar activity. Many folks told me it was irresponsible to report on it. Then the very same folks told me they were glad I was doing it because it gave them leverage when dealing with utilities—sort of a good cop, bad cop routine.

I was astounded when an installing dealer stood up and announced to the group that he'd installed thirteen guerrilla solar electric systems in the last three years. Even though his state has a net metering law, the utilities are blocking interties in the usual manner—huge insurance requirements, gold plated disconnects, and expensive, needless engineering reports. I was also amazed to discover how many of the ASES attendees were operating their own guerrilla solar systems. While I can't say who they are, or where they are, be assured that guerrilla solar activity is not restricted to the grassroots level; it is also occurring at the academic and professional levels.

MREF

While ASES was interesting and informative, I was glad to get on an airplane and head for the Midwest Renewable Energy Fair. MREF is my idea of the ultimate in fun—PVs out in the sun where they belong, wind gennys actually producing power, and thousands of folks who are now using RE in their own lives. See a pictorial report on MREA's tenth annual fair on page 50 of this issue.

Next year, MREF and ASES will join forces. These two energy events will run back to back in Madison, Wisconsin. We have high hopes that we can fuse the industry and academic side of RE with its grassroots users. Don't miss the MREF/ASES combo in Madison next year. Put these dates on your calendar: MREF 2000 on June 16–18 and ASES on June 19–22. Come and join us for an entire week of RE activities.

Guerrilla Solar

We finally have a Guerrilla Solar Manifesto; see page 77 of this issue. Guerrilla solar makes a difference—it's putting RE online where it belongs, it challenges the century-long utility monopoly, and it shows the powers-that-be that we are serious about RE and our desires to heal this planet.

I put out a call to guerrillas everywhere. Send us information about your activities and we'll publish it. We'd like to have 300–500 words describing your system—what your charging sources are, how you are using the RE, and *why* you are a solar guerrilla. And send us 4–6 photos to choose from. We will keep your identity and location top secret. Let's keep up the pressure—it's scaring the hell out of the utilities!

In order to clear up confusion about guerrilla solar, we have come up with a definition: *Guerrilla solar is the unauthorized placement of renewable energy on a utility grid.*

Trends in Renewable Energy

Those of you with email should be reading the newsletter *Trends in Renewable Energy,* published by Bill Eggertson of the Canadian Association for Renewable Energies. You can request a sample copy by emailing sample@renewables.ca, or you can subscribe by emailing subscribe@renewables.ca. It's free and well worth the read.

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Q&A

To Goo or Not to Goo
Dear Karen and Richard, I have a question which I think may also be of interest to your readers. Maybe you have already addressed it, but I could not find any reference. Several companies make a substance which is essentially a copper paste, used for reducing the resistance in terminal connections while also providing anti-oxidation and anti-seize benefits. Thomas and Betts (a large electrical supplier) is one source. What do you make of this? Should I use it when assembling my system components? Seems to me like a no-lose situation, except that it is somewhat expensive. Aluminum paste is much cheaper and more easily available but I think it's primarily used as an aluminum anti-oxidant. Just a minor point—thanks for your time. Geoff Yokum • Bfragrant@aol.com

Hello, Geoff. I am anti-goo. I've tried several varieties and have concluded that "tight and bright" is the best way to go with all connections. The only exception is when using aluminium wire or cable, then No-Ox goo is a necessity.

Over time all mechanical connections need to be polished bright and tightened—even if covered with conductive goo. In order to do this, the old goo must be cleaned off, which is difficult and messy. Go with tight and bright!

Controllers for Multiple Sources
Dear Mr. Perez, I am in need of advice regarding selection of appropriate charging equipment for a system being installed on my farm. Equipment selected to date includes two Trace 5548 inverters stacked for 120/240V, a 48 volt 700 AH battery bank, Platypus Hydro, 1,200 watts of solar panels, and a 15 KW diesel generator. My question is regarding selection of the charge controller(s) and possible inclusion of a pulse device to reduce sulfation. Platypus pushes their own charge controller which is complete with diversion load, and of course Trace would like to sell their offerings.

Should I use two charge controllers, or is a single controller adequate for this system, and if so, whose? Is there a single pulse unit that will be compatible with these three charging sources, i.e., generator, solar, and hydro, and where can it be found? If a pulse unit is not appropriate for all three charging sources, which one(s) should be integrated with it for the most benefit? The primary charging source will vary seasonally. Who manufactures the most suitable pulse unit, and where can it be obtained? Lee Mitchell • leemitch@ij.net

Hello Lee, I'd put individual regulators on the PV and the hydro. The Platypus regulator works great with their hydro, and I'd use it. The PWM charge controls I like best for PVs are made by Heliotrope (see their ad in any Home Power). *The electronic desulfator is not dependent on the charging source, so that isn't a concern. Check out the Power Pulse in the Abraham Solar ad in this issue. We've been using ours for three years now and have seen good results. Richard Perez*

Really BIG Batteries
Dear *Home Power,* My local air force base has big batteries that were removed from UPSs mounted in nuclear missile silos. I can get them for 0.01 cent per pound.

The batteries weigh 1,600 pounds each and are manufactured by Charter Power Systems (www.cdpowercom.com). Each one was removed after it failed a load test dropping under 80 percent capacity. Some have damaged tops or stripped filler caps, but load tested okay. The capacity is 635 AH at a 6 hour rate. They are 16 volts, plus or minus 2 volts.

Would these batteries be good for my off-grid system if I set up three of them for 48 volts? Logan & Jenni Bryce wlbryce@3rivers.net

Hello Logan. I'm leary of used lead-acid batteries. Most of the time they are a lot of trouble for a battery that will maybe last a while, but mostly won't. Also, how are you going to move a 1,600 pound battery? We have some 350 pounders here and moving them is a huge pain. Richard Perez

Controllers Without Batteries?
Hey there Richard, a quick "Can I do this?" question. I have two solar collectors (water heat) connected in a closed loop system. The system includes a high efficiency 18 watt DC permanent magnet motor/pump (purchased from AAA Solar) and an expansion tank. I am trying (operative word: "trying") to drive the motor by connecting it to a 17 watt solar panel and a charge controller (14 volts, 8 amp rating). The problem is that the motor won't always start running when the panel is exposed to the sun. When the panel is in the sun and I disconnect the positive lead between the charge controller and the motor and then reconnect the leads, the motor starts right up and runs fine. It will continue to run until a cloud causes the motor to stop, at which time I have to start it by disconnecting the positive lead again.

I discussed this problem with several of my engineering friends. They think the problem has to do with the fact that the motor (at rest) appears as a dead short to the charge controller, and so the charge controller won't pass the electricity on to the motor. I understand their

point, but it appears to me that the charge controller is allowing the panel voltage to be drawn down to almost nothing due to the starting current draw. The problem I have with my theory is that I thought the charge controller isolated the solar panel from the load. Thanks for any information you can give me. Daniel Wigant • DWigant@ElectroD.com

Hello Dan. Get rid of the charge controller. You don't need it and it's getting in the way of performance. If the PV will still not reliably start the motor, then you need a device called an LCB (linear current booster), which you can purchase from virtually any PV dealer. Your techie friends are partially right, the charge controller is probably not operating because it is designed to work with a battery in the circuit. Since you don't have a battery, the voltage may not be getting high enough to allow the charge controller to operate. Get an LCB and everything should work properly. Richard Perez

800 vs 900 MHz

Hi Richard, Did you at one time have an article on extending the range of an 800 MHz phone? I'm trying to extend mine to reach out and touch someone on my 40 acres. Scott Wilson • swilson@bigbear.com

Hello, Scott. No, we've never done an article on that although it's been discussed in our Letters *section. The best thing to do is replace your phone with one of the new 900 MHz 2 GHz spread spectrum cordless models. They work glitch-free at over 1/4 mile right out of the box.*

I believe C. Crane and Co (www.ccrane.com) sells a replacement long range antenna and the new spread spectrum cordless phones. Also, you can purchase hot-rodded cordless phones for remote use from Childs Play, 655 Redwood Dr., Garberville, CA 95440 • 707-923-2934. If you have any local ham friends, they could hotrod the antennas in an afternoon. Richard Perez

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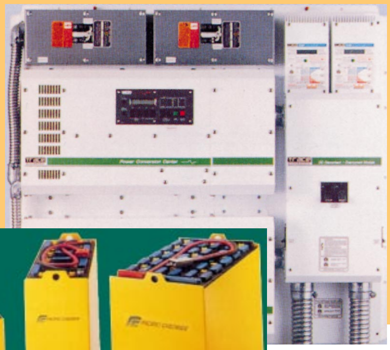

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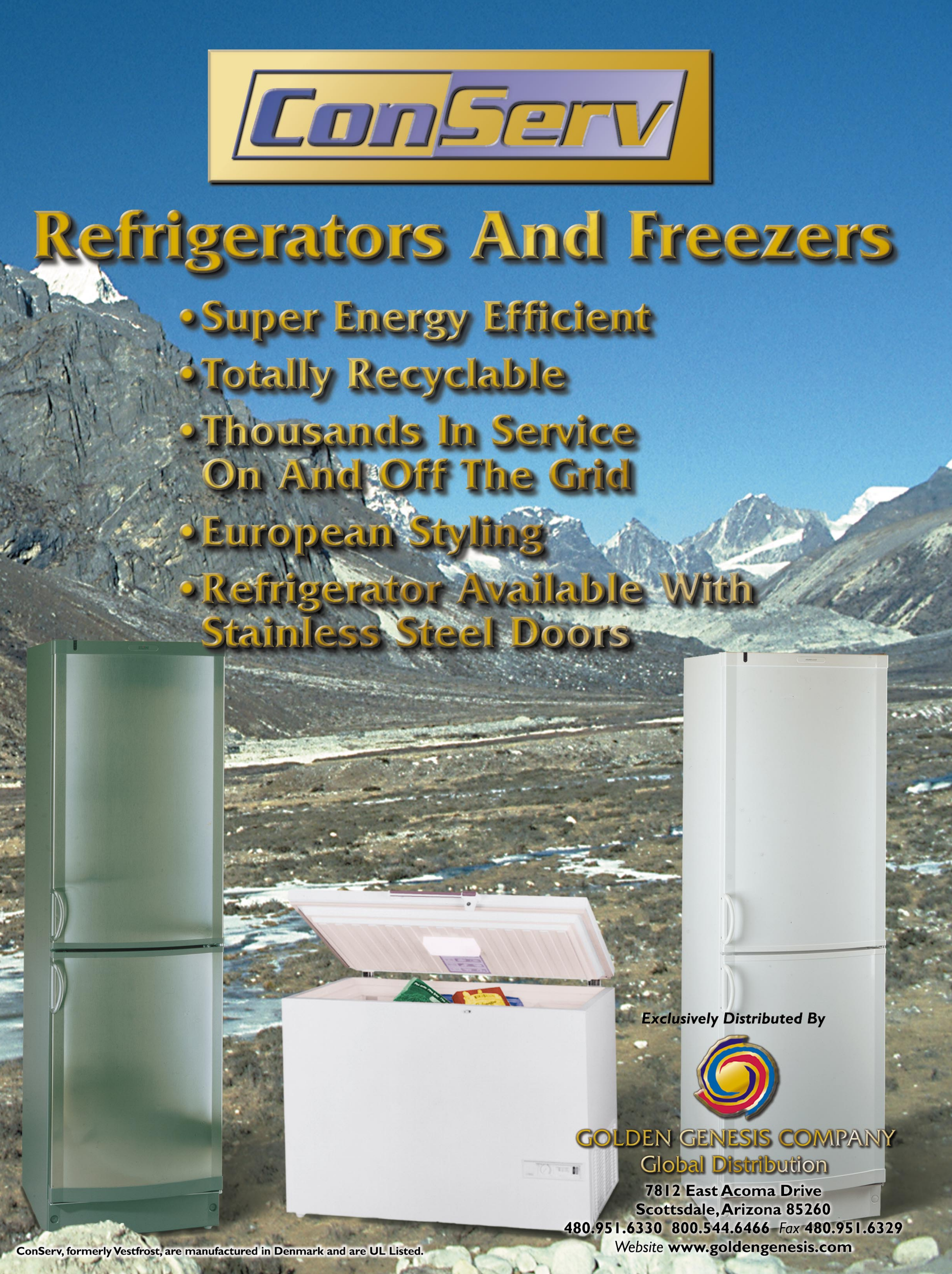
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